INCREASED REINFORCEMENT WHEN TIMEOUT FROM AVOIDANCE INCLUDES ACCESS TO A SAFE PLACE¹

ALAN BARON, RICHARD J. DEWAARD, AND JOEL LIPSON

UNIVERSITY OF WISCONSIN-MILWAUKEE

Three experiments investigated the reinforcing value of access to a safe place during timeout from an avoidance schedule. Rats were trained on conjoint schedules in which responding both postponed shock on a free-operant avoidance schedule and produced periods of timeout on fixed-ratio schedules. In some conditions, a shelf was inserted into the operant chamber during timeout, enabling subjects to get off the grid floor. The combination of timeout and shelf maintained substantially higher response rates than the baseline avoidance schedule with ratio requirements as high as 90 (Experiment I). Adding the shelf to timeouts in one component of multiple fixed-ratio schedules of timeout resulted in higher response rates in the component where the shelf was included (Experiment II). When timeouts with and without the shelf were arranged on concurrent schedules, the shelf-timeout combination was preferred, even when of shorter duration than timeout alone (Experiment III). In all three experiments, subjects climbed on the shelf, although all shocks were cancelled during timeout periods. The results could not be accounted for solely in terms of the reinforcing properties of changes in shock rates, but required an interpretation that ascribed conditioned reinforcing value to stimuli associated with such changes.

Key words: timeout from avoidance, safe place, conditioned aversive stimuli, fixed-ratio schedules, avoidance, lever press, rats

An unresolved issue in the analysis of aversive control concerns the source of reinforcement for avoidance behavior. One point of view, two-factor theory, holds that stimuli associated with primary aversive events acquire aversive properties through Pavlovian conditioning. The reinforcer for the avoidance response, then, is identified with the termination of these conditioned aversive stimuli (Mowrer, 1939; Schoenfeld, 1950).² An alternative position, which does not rely on classically conditioned mechanisms, identifies the reinforcer for avoidance responding with reductions in

the density of the primary aversive event (Herrnstein, 1969; Sidman, 1962a). According to this single-factor theory, the functions of stimuli associated with aversive events are discriminative and informative, rather than reinforcing.

Much of the evidence for the two-factor account comes from instrumental avoidance procedures in which the response, usually running or hurdle jumping, allows the subject to leave an area where shocks are scheduled, so that the consequences of responding include both termination of conditioned aversive stimuli and reductions in shock density. By comparison, evidence for the single-factor account often comes from the free-operant avoidance procedures developed by Sidman (1953), in which the subject is confined within the aversive environment, and the only scheduled consequence of the avoidance response, usually a lever press, is to postpone brief shocks. As Herrnstein (1969) and others (*e.g.*, Bolles, 1970) have pointed out, Sidman's procedure poses a special challenge for two-factor theory, since responding reduces shock rates under circumstances where it is not easy to identify conditioned aversive stimuli that are terminated.

¹Portions of the results were reported at the meeting of the Midwestern Association of Behavior Analysis, Chicago, May, 1975. Experiment I comprised the third author's Master's thesis, under the direction of the first author. Thanks are due to Edwin Giese for his assistance in designing the apparatus, and to Ronald Kral, Gregory Jurenc, Robert Prosser, and Douglas Payerl for help in collecting and analyzing the data. Reprints may be obtained from Alan Baron, Department of Psychology, University of Wisconsin-Milwaukee, Milwaukee, WI 53201.

²Some versions of two-factor theory call attention to stimuli negatively correlated with aversive events, that is, stimuli associated with the absence of aversive events, whose production by the avoidance response is reinforcing (Denny, 1971; Dinsmoor and Sears, 1973).

An untapped strategy for contrasting these two accounts of avoidance is through procedures in which a response has the dual consequences of avoiding shock and allowing the subject to leave the aversive environment. If reductions in shock density are the sole basis for the reinforcement of avoidance behavior, there is little reason to expect different outcomes when shock-free periods are spent inside and outside the aversive environment. By comparison, if termination of stimuli correlated with shocks is reinforcing, then escape from the aversive environment should add to the reinforcing potential of shock-free periods.

Two studies adopted the above strategy, both using instrumental avoidance procedures and group designs (Masterson, 1970; Wahlsten, Cole, Sharp, and Fantino, 1968). The general findings were that when a lever press allowed escape from the conditioning chamber, performances were superior to a control condition in which the response simply avoided shock. But interpretation of these results as supporting the two-factor theory of avoidance is clouded by the additional finding of Wahlsten *et al.* that the handling needed to replace subjects in the conditioning chamber was sufficient to account for the effect. Members of a control group handled during the intertrial interval but not allowed to escape, performed as well as experimental subjects.

The present experiments studied the reinforcing properties of escape from an aversive environment using free-operant rather than instrumental avoidance procedures and an apparatus not requiring handling of subjects. Rats were trained on conjoint schedules in which the lever-press response both avoided shock and produced periods of timeout from the avoidance schedule. During these timeout periods, subjects could jump up on a shelf inserted into the chamber (Baum, 1965), and in this way escape from the grid and other stimuli chronically correlated with shock. Since several experiments have shown that timeout from an avoidance schedule is, of itself, reinforcing (Baron and Trenholme, 1971; Sidman, 1962*b*; Verhave, 1962), an essential part of the present procedure was to determine the extent to which the opportunity to jump onto the shelf added to the reinforcing properties of timeout alone.

Three experiments are reported, all using a free-operant avoidance baseline in both com-

ponents of a multiple schedule. In Experiment I, a fixed number of avoidance responses in one component also produced periods of timeout from avoidance, and the size of the fixed ratio and the presence or absence of the shelf during timeout periods were varied. Experiment II assessed the reinforcing properties of the shelf more directly by making the shelf-timeout combination available in one component and contrasting it with timeout alone in the other. Finally, Experiment III used concurrent schedule procedures in one component of the multiple schedule to evaluate choice between timeouts with and without the added shelf.

GENERAL METHOD

Subjects

Fifteen experimentally naive, male albino rats, 90 to 120 days old at the start of the experiments, were housed throughout in individual cages with free access to food and water.

Apparatus

Two specially constructed chambers, 29.2 cm long, 22.2 cm wide, and 28.5 cm high, were enclosed in sound-attenuating chests. The two shorter walls and the ceiling were constructed of Plexiglas, the longer walls of aluminum, and the floor of stainless steel rods at 1.3-cm intervals. A retractable lever (BRS/LVE, RRL-015), operated by a force of approximately 0.3 N, was positioned 10.8 cm above the floor in the center of one aluminum wall. A 6-W lamp, mounted behind translucent white plastic on a side wall, illuminated the chamber.

To allow subjects to get off the grid floor, a Plexiglas shelf could be inserted through a slot in the wall opposite the lever. The shelf was 23.5 cm wide, 15.2 cm above the grid floor, and extended 6.3 cm into the chamber when fully inserted. A reversible electric motor required 1.5 sec to insert or retract the shelf. A photocell and light source, mounted on opposite side walls, recorded whether the subject was on the shelf.

A view of the apparatus with a subject on the shelf is shown in Figure 1. The door of the chamber, one Plexiglas wall, is open to make the interior more visible. As was always the case when the shelf was inserted, the lever, on the wall to the left, is retracted. The houselight and photocell light source may be seen attached to the door.

Fig. 1. Interior of the experimental chamber with the shelf inserted and the lever (on left wall) retracted. The door, ordinarily closed, is opened to make the interior more visible.

A constant-current shock generator (Grason-Stadler, E1064GS) delivered scrambled shock to the grid floor. White masking noise was continuously present except when replaced by a pure tone (1000 Hz for some subjects and 3500 Hz for others) when the shelf was in the chamber.

Preliminary Training

Before the procedures described individually for each experiment, subjects were trained in the following ways: (a) to jump on the shelf to avoid shock, (b) to press the lever to avoid

shock, and (c) to perform on a two-component multiple schedule with free-operant avoidance in one component and conjoint schedules of avoidance and timeout with the shelf in the other.

Shelf training. With the lever retracted, the shelf was inserted into the chamber, and 5 sec later 0.8-mA continuous shock was applied to the grid floor. The shelf was retracted after 50 sec, and the subject spent a 30-sec interval on the uncharged floor before the next trial began. There were 50 to 80 training trials over one or two sessions, at which point all subjects

were avoiding shock on at least 90% of the trials.

Lever-press avoidance. With the shelf retracted, subjects were trained to press the lever to avoid shocks of 0.8-mA intensity and 0.3-sec duration. Lever pressing first was shaped and then maintained by a free-operant avoidance schedule in which each response postponed shock for 20 sec (the response-shock interval) and subsequent shocks were scheduled at 5-sec intervals if a response was not made (the shock-shock interval). Training continued for a minimum of 30 hr in 3.0- to 3.5-hr sessions conducted on alternate days.

Multiple schedule. The two components were distinguished by illumination of the chamber. Lever-press responses during S1 (darkness in Experiment I and illumination in Experiments II and III) avoided shock as described above. The S2 component contained a conjoint schedule in which responses had the dual consequences of avoiding shock and producing the shelf. Insertion of the shelf was accompanied by pure tone, retraction of the lever, and omission of all shocks. The shelf was retracted after 45 sec, at which time the lever was re-inserted, the pure tone terminated, and the avoidance schedule reinstituted with the first shock scheduled 20 sec later, the duration of the response-shock interval. Thus, subjects could sit on the shelf during a 45-sec period of timeout from the avoidance schedule.

Initially, a single response in S2 produced timeout and the shelf. In a series of steps, the fixed-ratio (FR) requirement was increased from one to 10, and training continued at FR 10 until performance was judged stable.

Response measures taken in the S2 component of the schedule included rates of lever pressing, interresponse times, the latency to the first response following retraction of the shelf (the postreinforcement pause), and time spent on the shelf. To obtain comparable lever-press data in the S1 component when the shelf was not scheduled, uninterrupted avoidance responding was sampled, with the data collected *as if* the shelf had been inserted into the chamber. Thus, although the shelf was not inserted and the avoidance schedule was in no way changed, completion of a fixed number of responses in S1 produced a 45-sec period when all recording operations were suspended.

The components of the multiple schedule alternated every 30 min in Experiments I and

III and every 5 min in Experiment II. Component durations were extended as needed so that a transition from one component to the other occurred only at the end of a timeout or suspension of recording operations. The session length during this and all subsequent phases was 3.5 hr, with the first 30 min constituting a warm-up period when S1 and S2 durations were abbreviated to 15 min each and data were not collected.

As a control procedure, equivalent schedules (either free-operant avoidance alone or conjoint avoidance and timeout) were arranged in both components to establish that the stimuli defining the components did not control different response rates.

EXPERIMENT I

The purpose of the first experiment was to examine the characteristic behaviors controlled by the shelf contingency. The fixed ratio required to produce the shelf was increased until an upper limit was reached, and the role of the timeout periods that accompanied the shelf was evaluated in a preliminary fashion.

Procedure

Eight subjects were used. When preliminary training was completed, the fixed ratio required to produce the shelf in S2 was progressively increased in steps of five or 10. Transitions to larger ratios usually were smooth, but occasionally it was necessary to return to earlier ratio values. As a rule, three sessions were devoted to each ratio value, although training sometimes involved as few as two and as many as 10 sessions.

The sequence of increasing fixed ratios was terminated for each subject when consistent differences were no longer apparent between rates to produce the shelf in S2 and baseline avoidance rates in S1. On this basis, three subjects (R3, R5, and R7) reached FR 90. Of the others, one completed FR 50 (R11), two completed FR 40 (R1 and R6), and one completed FR 30 (R9) before training was terminated. The last subject (R2) became ill midway in the experiment and was not tested beyond FR 30.

At various points in the procedure, the shelf was omitted from timeout periods in a series of probe sessions. During these probes, usually three or four sessions long, other features of the procedure were left unchanged, *i.e.*, on

completion of the ratio in S2, the lever was retracted, all shocks were omitted, and the pure tone replaced white noise for 45 sec. An additional manipulation in some cases was to increase the duration of shelf periods or timeout periods without the shelf from 45 to 160 sec.

RESULTS AND DISCUSSION

Figure 2 summarizes the results in the form of mean interresponse times. Separate values are plotted based on avoidance responding in S1 (dashed lines) and responding on conjoint avoidance and timeout in S2 (solid lines) during the final session at each fixed ratio. The

mean interresponse times were based on the time from the first to the last response of the fixed ratio. That is, the latency to the first response of the ratio in both S1 and S2 was excluded from the calculations.

The first pair of points for each subject shows performance during the stimulus adaptation phase (A) when only free-operant avoidance was scheduled in both components. Approximately equal rates were maintained in the two components, indicating that the stimuli defining the components did not contribute systematically to subsequent differences.

The rest of Figure 2 shows results when the shelf was scheduled according to increasing

Fig. 2. Experiment I: mean interresponse times during adaptation (A) and across fixed-ratio requirements ranging from FR 10 to the highest ratio reached by each subject. The baseline avoidance schedule was arranged in S1 (dashed lines) and conjoint schedules of avoidance and timeout with the shelf in S2 (solid lines). Data are from the final session in each condition.

fixed ratios. The shelf contingency had major effects on performance in the S2 component. In all subjects, mean interresponse times decreased markedly from adaptation to FR 10, and at all subsequent ratio values, interresponse times were substantially shorter in S2 than in S1, with the single exception of Subject R2 at FR 30. By comparison with the avoidance baseline, conjoint avoidance and fixed-ratio shelf presentations increased response rates by a factor of 1.5 to 6.0.

Figure 2 also indicates that the function relating mean interresponse times to fixed-ratio size differed from subject to subject. For most subjects, interresponse times in S2 increased gradually with increasing fixed ratios, but the times of two subjects (R3 and R7) were relatively constant until the terminal value of FR 90 was reached, and the times of one subject (R5) only increased following FR 50. Interresponse times on the avoidance schedule in S1 also varied, remaining more or less constant for some subjects (*e.g.*, R5 and R7), and decreasing (*e.g.*, R2 and R9) or increasing (*e.g.*, R1) for others.

Interresponse-time distributions allow a more detailed analysis of the effects of the shelf contingency. Figure 3 presents these data for the three subjects trained up to FR 90. During adaptation, S1 and S2 distributions (open and solid bars, respectively) were very similar and show spaced responding typical of free-operant

avoidance schedules. Subsequent conjoint scheduling of avoidance and timeout resulted in shifts toward shorter interresponse times in S2 and less-marked shifts toward longer times in S1. In most cases, at least half of all S2 responses were in the first interval, *i.e.*, within 4 sec of the preceding response. Thus, the fixed-ratio schedules of shelf presentation replaced the pattern of spaced responding controlled by the avoidance schedule with much higher rates of responding. As a consequence, fewer shocks were received in the component containing the shelf, as indicated by the low percentage of responses falling in the last (shock-shock) interval of the distribution.

There was no systematic relationship between ratio size and the duration of the postreinforcement pause, the latency to the first response of the ratio in S2. Other studies using both positive (Felton and Lyon, 1966; Powell, 1968) and negative reinforcement (Azrin, Holz, and Hake, 1962; Sidman, 1962*b*) have shown that the postreinforcement pause increases with increasing ratio requirements. In the present study, however, scheduling procedures limited the extent of pausing at the start of the ratio. Because shock avoidance and timeout were contingent on the same response, pauses longer than 20 sec were punished by shock every 5 sec (the shock-shock interval). Nevertheless, the pause-and-run pattern characteristic of fixed-ratio performance was evi-

Fig. 3. Experiment I: interresponse-time distributions of three subjects during the final session of adaptation and at selected fixed-ratio values. The baseline avoidance schedule was arranged in S1 (open bars) and conjoint schedules of avoidance and timeout with the shelf in S2 (solid bars).

dent. Median postreinforcement pauses for individual subjects across ratio values ranged from 10 to 16 sec, and, except for Subject R1 at FR 40, postreinforcement pauses were substantially longer than mean interresponse times at all ratio values.

Although all shocks were cancelled whenever the shelf was in the chamber, subjects spent substantial amounts of time off the grid floor and on the shelf. With only rare exception were these times below half of the total possible, and during the final session on the largest fixed ratio for each subject, they ranged from 60% to nearly 100% of the time. While subjects varied in amount of time spent on the shelf, this behavior was not clearly related to rates of responding to produce the shelf.

A total of 10 sets of probe sessions were conducted with the shelf omitted from timeout periods. Absolute response rates were variable in these comparisons, but the effects were orderly when analyzed in terms of relative response rates expressed as the ratio of response rates in S2 to baseline avoidance rates in S1. During the sessions immediately preceding the probes, when timeouts included the shelf, relative rates ranged from 1.7 to 3.5 with a median for the 10 comparisons of 2.5. Omission of the shelf from timeout periods systematically reduced relative rates in all 10 of the probes to the range of 1.1 to 2.4 with a median value of 1.5.

In seven of the 10 probes, omission of the shelf from timeout periods also led to increased postreinforcement pauses. During the sessions preceding these seven probes, postreinforcement pauses ranged from 10.5 to 21.8 sec, with a median value of 15.6 sec. During the seven probes, pauses ranged from 13.0 to 27.6 sec, with a median of 17.6 sec. This effect is similar to the finding that postreinforcement pausing increases as the amount of positive reinforcement is decreased (*e.g.*, Powell, 1969). However, in three probes (occurring in two subjects, R6 and R9), this effect was reversed; postreinforcement pauses decreased when the shelf was omitted from timeout.

Finally, the effects of omitting the shelf were independent of fixed-ratio value and timeout duration. Probes conducted at ratio values ranging from FR 20 to FR 90 for different subjects yielded similar outcomes, as did probes involving timeout durations of 160 instead of 45 sec.

In summary, the results showed that insertion of the shelf into the chamber was a potent reinforcer. Lever-press rates were substantially higher on conjoint free-operant avoidance and fixed-ratio shelf than on the avoidance schedule alone, and this difference was maintained with ratios as high as FR 90. The results also suggested that the shelf possessed reinforcing properties above and beyond those associated with timeout from avoidance. Relative response rates were higher and postreinforcement pauses usually were shorter when responding produced the shelf than when responding produced timeout without the shelf. A correlated finding was that subjects spent significant amounts of time on the shelf, even though all shocks on the grid were cancelled during timeout.

EXPERIMENT II

Periods of timeout from avoidance with and without access to the shelf were compared more directly and systematically in the second experiment. Timeout periods were scheduled in both components of the multiple schedule with the shelf accompanying timeout in S2 but not in S1. Subsequent manipulations compared timeouts with and without the shelf under two additional conditions. First, shocks were scheduled during shelf periods, effectively requiring subjects to climb on the shelf during timeout. Second, the shelf was retracted immediately following insertion, thus providing the stimulus change associated with presentation of the shelf without the usual opportunity to climb on it.

Procedure

Five new subjects were used. At the end of preliminary training, the duration of the multiple schedule components was reduced from 30 min to 5 min for the remainder of the experiment. It was anticipated that shorter component durations would provide a more sensitive evaluation. After subjects had adjusted to the shorter durations, the FR 10 schedule of shelf presentations was arranged in both S1 and S2 to establish equal performances (two to three sessions).

The different conditions of Experiment II and the number of sessions devoted to each are shown in the first two columns of Table 1. Initially, the shelf accompanied timeouts in

S2 and was omitted from timeouts in S1 (Condition 1). Other consequences of responding were identical in both components: following the tenth response, the lever was retracted, the tone was presented, and shocks were cancelled for 45 sec. After two sessions in which Subject D4 showed minimal performance differences between the components (substantial differences were apparent in the other four subjects), the auditory stimuli accompanying timeout were changed so that a different tone (3500 Hz) signalled timeout in S1, while the original tone (1000 Hz) continued to signal the shelf-timeout combination in S2.

Variations in time spent on the shelf raised the question of whether lever-press rates would vary if climbing on the shelf was, in effect, required instead of merely allowed as in the previous comparison. Thus, a single, brief (0.3 sec) shock was applied to the grid floor 10 sec after onset of timeout in both the S1 and S2 components (Condition 2). This extra shock was unavoidable in S1, but could be avoided by climbing on the shelf in S2. The shock then was removed from timeout periods in S1, but retained in shelf periods in S2 (Conditions 3 and 4). For Subject D4, different tones accompanied timeouts with and without the shelf, as described above. The other four subjects were observed first with the same tone (Condition 3) and then with different tones accompanying timeouts in S1 and S2 (Condition 4). The latter procedure remained in effect for the remainder of the experiment.

Insertion of the shelf introduced a unique stimulus change in addition to providing an opportunity to climb off the grid floor. To determine the influence of this change, the additional shock in shelf periods was no longer delivered and the shelf was retracted immediately following its insertion (Condition 5). Thus, while the tenth response in S2 produced the shelf, its retraction forced subjects to remain on the grid floor for the duration of the timeout period. Subjects D1, D5, D12, and D13 served in this condition.

To recover previous comparisons of timeout with and without access to the shelf, the four subjects that served in the brief shelf condition then were returned to the multiple schedule of timeout without the shelf in S1 and timeout with the shelf and added shock in S2 (Condition 6). After additional sessions with only free-operant avoidance schedule in both compo-

nents (Condition 7), the original multiple schedule of timeout with and without the shelf and no additional shocks was reinstituted for all five subjects (Condition 8).

RESULTS AND DISCUSSION

Figure 4 presents mean interresponse times in S1 (solid circles) and S2 (open circles) at the end of preliminary training and during Condition 1. Table 1 summarizes the entire experiment (Conditions 1 to 8) in terms of mean interresponse times and their ranges over the last four sessions in each condition. As was the case previously, the time to the first response of the fixed ratio was excluded from calculations of mean interresponse times in both S1 and S2.

The first two panels of Figure 4, which summarize performances at the end of preliminary training, show results similar to those obtained in Experiment I. By comparison with S1, the component with the baseline avoidance schedule, mean interresponse times were substantially shorter in S2, the component with the FR 10 schedule of timeout and shelf. The second panel shows that when timeout and the shelf were added to S1, interresponse times dropped rapidly to levels associated with S2.

The relative contribution of the shelf to the reinforcing effects of timeout may be seen in the third panel of Figure 4 and the first row of Table 1. When the shelf was omitted from timeout periods in the S1 component but included in S2, S1 mean interresponse times of four subjects increased to levels intermediate to those maintained by the avoidance schedule alone and by the schedule of shelf presentations. This difference in component response rates was present over the 10 sessions in this condition, although it decreased over sessions for Subject D1. By comparison with the others, the fifth subject, D4, showed equally short interresponse times in both components, and use of different tones to signal timeout with and without the shelf (Sessions 9 to 11) had no effect.

During preliminary training and Condition 1, subjects spent considerable amounts of time on the shelf, but unlike Experiment I, this behavior decreased with continued training. In the terminal sessions of Condition 1, Subjects D5 and D12 were on the shelf approximately 80% of the total possible time, Subject D1 was on the shelf approximately 35% of the time,

Fig. 4. Experiment II: mean interresponse times in S1 (solid circles) and S2 (open circles) over sessions at the end of preliminary training and during Condition 1.

Table 1

Experiment II: mean interresponse times in the S1 and S2 components of the multiple schedule. Values are means of the last four sessions in each condition with ranges given in parentheses.

Condition	Sessions	Subject				
		D1	D4	D5	D12	D13
(1) S1 Timeout	5-10	4.06 (0.55)	1.79 (0.59)	4.92 (0.99)	2.91 (0.99)	4.98 (0.81)
S2 Shelf		3.09 (0.82)	1.86 (0.46)	2.76 (1.42)	1.42 (0.43)	2.53 (0.69)
(2) S1 Timeout + Shock	4	6.65 (1.86)	9.20 (3.80)	7.92 (1.51)	5.61 (2.74)	7.04 (3.27)
S2 Shelf + Shock		1.84 (1.12)	4.16 (1.64)	2.58 (1.30)	1.19 (0.39)	2.83 (1.99)
(3) S1 Timeout (same tone)	10	4.53 (1.98)	Not run	3.79 (1.10)	3.50 (0.54)	4.77 (1.23)
S2 Shelf + Shock		1.86 (0.62)		1.94 (0.34)	2.05 (0.63)	2.70 (1.19)
(4) S1 Timeout (diff. tone)	10-14	3.83 (0.61)	1.90 (0.56)	4.20 (0.54)	3.37 (0.96)	3.84 (1.11)
S2 Shelf + Shock		2.18 (1.01)	2.78 (0.67)	2.06 (0.17)	2.26 (0.90)	2.03 (0.46)
(5) S1 Timeout	4-8	3.04 (0.60)	Not run	4.47 (0.65)	3.84 (1.00)	4.11 (0.88)
S2 Brief Shelf		2.95 (0.80)		4.52 (1.32)	3.35 (0.50)	4.18 (1.07)
(6) S1 Timeout (diff. tone)	4	2.99 (0.54)	Not run	4.35 (0.77)	3.09 (0.55)	4.58 (1.13)
S2 Shelf + Shock		1.83 (0.47)		2.27 (0.54)	2.27 (0.45)	3.19 (1.52)
(7) S1 Avoidance only	4-8	8.46 (1.12)	9.83 (1.68)	5.69 (1.28)	5.59 (1.11)	6.17 (0.63)
S2 Avoidance only		8.35 (1.37)	9.80 (1.55)	5.69 (0.76)	5.13 (1.13)	6.25 (1.93)
(8) S1 Timeout	6-12	3.24 (0.22)	2.24 (0.46)	4.11 (1.18)	3.96 (1.09)	6.21 (0.95)
S2 Shelf		1.46 (0.55)	2.68 (0.28)	1.93 (0.34)	1.91 (0.40)	4.85 (0.52)

and Subject D13 about 15% of the time. For these four subjects, there was no systematic relationship between lever-press rates and time spent on the shelf. However, Subject D4 did not show differences in interresponse times as a function of the shelf, and also rarely climbed on the shelf when it was in the chamber; at most, 5% of the time.

When a brief shock was delivered 10 sec after the onset of timeout periods with and without the shelf (Row 2, Table 1), interresponse times increased in S1 where the shock was unavoidable, and were not changed systematically in S2 where the shock could be avoided. Subjects jumped on the shelf promptly and avoided most of the shocks scheduled in shelf periods. In this and subsequent conditions in which shock was scheduled in shelf periods, time spent on the shelf exceeded 90% of the possible time.

Rows 3 and 4 of Table 1 show that the four subjects that previously had shorter interresponse times in the shelf component continued to respond at higher rates in S2 when an added shock was scheduled during shelf periods, and it made little difference whether the same or different tones signalled timeout and shelf periods in the two components. By comparison, the atypical subject, D4, showed small but consistent rate differences in favor of timeout without the shelf when shock was scheduled during shelf periods.

The effects of retracting the shelf immediately following its insertion are shown in Row 5 of Table 1. Mean interresponse times in S2, the shelf component, increased to levels approximately equal to those maintained by timeout without the shelf.

The last three rows of Table 1 summarize results when earlier conditions were reinstituted. When the four subjects, excluding D4, were returned to the multiple schedule of timeout alone in S1 and timeout with the shelf and added shock in S2 (Row 6), the difference in interresponse times in favor of the shelf was regained, although times varied somewhat from previous levels. When only free-operant avoidance was scheduled in both components (Row 7), approximately equal and much longer interresponse times were recovered. Finally, when the original multiple schedule comparing timeout with and without the shelf was reinstituted, shorter interresponse times in S2 were recovered in four subjects

(Row 8). Subject D4 again responded at approximately equal rates in both of the components.

As was the case in Experiment I, pauses following timeout with the shelf generally were shorter than pauses following timeout alone. Across all subjects in Conditions 1 and 8, median postreinforcement pauses were 13.4 sec in S1 (range = 11.3 to 20.4 sec) and 11.2 sec in S2 (range = 9.5 to 14.1 sec); differences between pauses in S1 and S2 ranged from 0.8 to 10.5 sec with a median of 1.8 sec. The procedure of briefly presenting the shelf in S2 timeout periods (Condition 5) eliminated differences in postreinforcement pausing, and the effects of adding shock to shelf periods (Conditions 3, 4, and 6) were not systematic.

The results of Experiment II showed that periods of timeout from avoidance, which include the opportunity to escape to the shelf, maintained higher response rates than timeout alone. This finding cannot be attributed to differing amounts of stimulus change accompanying the shelf-timeout combination and timeout alone because response rates were equal and at the level maintained by timeout alone when the shelf was briefly presented at the beginning of timeout periods. Rather, at least for four subjects, the opportunity to get off the grid floor appeared to be the critical variable.

The shelf-timeout combination also maintained higher response rates when an added shock forced subjects to climb on the shelf. Other experiments have shown that while potential shock determines the response rate in a given condition, the shocks actually received determine the reinforcing value of that condition (Hake, 1968; Rachlin and Herrnstein, 1969). In the present case, subjects almost always avoided the extra shock, and the reinforcing effect of the shelf was not diminished.

EXPERIMENT III

The finding that the shelf-timeout combination maintained higher response rates than timeout alone implies that subjects should choose the shelf in preference to timeout alone. Experiment III used concurrent fixed-ratio schedules to study this question. In addition, the extent of preference for the added shelf was evaluated by allowing subjects to choose between shorter periods of the shelf-timeout

combination and longer periods of timeout without the shelf.

Procedure

Two subjects served. The front wall of the chamber was replaced by a wall containing two retractable levers centered 13.3 cm apart, 10.8 cm above the grid floor.

Following jump-up avoidance training with the shelf, initial lever-press training on the free-operant avoidance schedule was conducted with one lever at a time inserted into the chamber. Once the response was acquired, both levers always were present. Throughout the experiment, a response on *either* lever began a new response-shock interval.

The procedure took into account the results of the first two experiments, which suggested that tendencies to jump on the shelf were most persistent when the conjoint avoidance and timeout schedules in one component of the multiple schedule were juxtaposed with only the avoidance schedule in the other component. For this reason, the concurrent schedules of shelf and timeout were inserted into one component (S2) of the multiple schedule, while the other component exclusively involved free-operant avoidance (S1). During S1, the chamber was illuminated; during S2 it was dark.

Within the S2 component, concurrent fixed-ratio schedules to produce the shelf were arranged in a nonindependent fashion (Shull and Pliskoff, 1971), that is, responses on either lever counted toward the fixed-ratio requirement. Initially, a single response produced a 45-sec period of timeout plus shelf, and subsequently, the response requirement was increased to FR 10. In the main phases of the experiment, different consequences were arranged for the tenth response, depending on whether it was made on the left or right lever. Thus, all responses in S2 both postponed shock and counted toward the fixed-ratio requirement for shelf presentation while, as in Experiment I, the only consequence of responding in S1 was the postponement of shock.

Before addressing questions about relative preferences for timeout with and without the shelf, it was important to show that the concurrent schedules in S2 would result in discriminative control, depending on the lever on which the FR 10 requirement was completed. During a series of sessions, the consequences of completing the FR 10 requirement on the

two levers were made substantially different. The tenth response on one lever produced the 45-sec period of timeout plus shelf, whereas the tenth response on the other lever returned the subject to the S1 component (avoidance only) for 45 sec. With these procedures, both subjects showed clear and reversible preferences for the lever producing the shelf, emitting at least 80% of their responses in S2 on the shelf lever and producing the shelf more than 90% of the time. Thus, it was concluded that the procedure was sufficiently sensitive to allow assessment of the effects of deleting the shelf from timeout periods.

Table 2 summarizes the procedures followed in subsequent phases of Experiment III and gives the number of sessions devoted to each condition. Conditions are specified in terms of the duration of the shelf-timeout combination and the lever that produced it.

In the first condition, equal periods of timeout with and without the shelf were compared. Depending on which lever the FR 10 schedule was completed (given in Table 2 for each subject), the tenth response produced either the shelf and timeout or timeout without the shelf.

Table 2

Experiment III: order of conditions and numbers of sessions in each condition. Responding on one of the two levers produced timeout periods of 45-sec duration in all conditions. Responding on the other lever produced timeout accompanied by insertion of the shelf for durations ranging from 5 to 45 sec. The association of left and right levers with the two consequences was reversed at least once within each condition.

Shelf Duration	Subject E3		Subject E4	
	Lever Producing Shelf	Number of Sessions	Lever Producing Shelf	Number of Sessions
(1) 45 sec	Right	10	Left	5
	Left	10	Right	16
	Right	6	Left	8
(2) 30 sec	Left	17	Right	6
	Right	6	Left	8
(3) 15 sec	Left	12	Right	10
	Right	10	Left	10
(4) 5 sec	Left	13	Right	8
	Right	12	Left	23
(5) 15 sec	Left	15		
	Right	10		
(6) 30 sec	Left	14		
	Right	6		
(7) 45 sec	Left	12		
	Right	12		

To ensure that preferences were not a result of lever bias or perseveration, the correlation of levers and outcomes was reversed twice.

All conditions and reversals were continued until choice performance was stable. The stability criterion required that, in the absence of a trend over four consecutive sessions, the daily per cent responses and per cent reinforcements fall within 5% of their respective four-day means.

In Conditions 2, 3, and 4, the duration of the timeout periods with the shelf was reduced in steps from 45 sec to 30, 15, and finally, 5 sec. During these conditions, the duration of timeout periods without the shelf, contingent on the tenth response on the other lever, remained 45 sec. Each shelf duration remained in effect until choice performance was stable, at which point the correlation of levers and outcomes was reversed.

Due to the death of E4, only Subject E3 participated in the final three conditions. In this series of increasing durations, shelf periods were increased from 5 to 15, 30, and 45 sec (Conditions 5, 6, and 7, respectively). As before, the duration of timeout without the shelf was 45 sec, conditions were continued until choice performance was stable, and the correlation of levers and outcomes was reversed at each shelf duration.

RESULTS AND DISCUSSION

Throughout the experiment, responding on the baseline avoidance schedule in S1 was maintained without difficulty or disruption by the conditions arranged in S2. Thus, these data will not be considered further.

The findings of greatest interest concern choice behavior on the concurrent schedules of shelf and timeout arranged in S2. These data are summarized in Figure 5, which shows per cent reinforcements (upper panels) and per cent responses (lower panels) on the level producing the shelf. Closed and open circles represent performances when the shelf was scheduled on the left and right levers, respectively, and data from the increasing series (E3 only) are indicated by dashed lines. Each point in Figure 5 is the mean of the last four sessions in each condition.

Per cent reinforcements, given in the upper panels of Figure 5, reflect the number of times timeout plus shelf was produced in preference to timeout alone. With equal 45-sec durations,

the shelf was preferred to timeout alone; both subjects produced it close to 100% of the time. This preference was manifested through two reversals of the levers associated with the two outcomes. The upper panels also show that the shelf was preferred when its duration was shorter than the timeout period without the shelf. When the shelf duration was reduced to 30 and then 15 sec, timeout with the shelf was chosen 90% or more of the time over the 45-sec period of timeout alone. It must be emphasized that these preferences were not simply a function of perseveration of the response strengthened in the previous condition, since the correlation of levers and outcomes was systematically reversed between and within conditions.

With the further reduction in shelf duration from 15 to 5 sec, the 45-sec period of timeout alone was preferred to the shelf period. Except when the 5-sec shelf was on the left lever for Subject E4, both subjects chose the 45-sec timeout virtually exclusively.

On the series of decreasing shelf durations, then, the preferences shown in the upper panels of Figure 5 conform to the all-or-none choice functions characteristic of concurrent ratio schedules of positive reinforcement. When one of a pair of concurrent ratio schedules requires fewer responses or provides greater amounts of reinforcement, preference for that alternative is nearly exclusive (Herrnstein, 1958; Herrnstein and Loveland, 1975; Rachlin and Green, 1972).

The ascending series of shelf durations, pursued only with Subject E3, also indicated that shorter shelf periods were preferred to longer periods of timeout without the shelf, and that reversal of preference was fairly abrupt. However, these data qualify conclusions regarding the extent of preference for the shelf, since choice of the shelf was not recovered until shelf duration was increased to 30 sec.

Choice functions based on per cent responses, summarized in the lower panels of Figure 5, are similar to per cent reinforcements insofar as both subjects made the majority of responses on the shelf lever at durations of 45, 30, and 15 sec, and per cent responses dropped from these levels when the shelf duration was 5 sec. As with per cent reinforcements, previous performance levels were not recovered on the ascending series until shelf duration was 30 sec.

Since the concurrent schedules were ar-

Fig. 5. Experiment III: per cent reinforcements (upper panels) and per cent responses (lower panels) on the lever producing the shelf as a function of the duration of timeout periods with the shelf. At each duration, the shelf was arranged on both the left (solid circles) and right (open circles) levers. Timeout without the shelf was always 45 sec in duration and arranged on the other lever. The increasing series of shelf durations for Subject E3 is indicated by dashed lines. The plotted points are means of the last four sessions in each condition.

ranged nonindependently, per cent reinforcements equals the relative rate of the tenth response, whereas per cent responses, or relative response rate, takes into account all 10 responses. Thus, deviations of per cent responses from per cent reinforcements were possible and are evident in Figure 5. These deviations took two forms. First, per cent responses were less extreme than per cent reinforcements. As a rule, the tenth response occurred consistently on one or the other lever, but the remaining responses were distributed to varying extents

on the two levers. Second, there were substantial lever biases, with Subject E3 favoring the right lever and Subject E4 the left. The consequence was that preference expressed as per cent responses was attenuated when subjects preferred the outcome associated with the non-preferred lever.

For both subjects, the time required to complete the FR 10 requirement increased as the duration of the shelf was reduced. At the initial duration of 45 sec, mean interresponse times, averaged over reversals, were 1.7 sec for

E3 and 1.5 sec for E4. Corresponding times when the shelf duration was 5 sec and both subjects chose timeout without the shelf were 4.0 sec (E3) and 6.5 sec (E4). Postreinforcement pausing varied systematically only in Subject E3, which showed a pattern similar to that for mean interresponse times. The shortest postreinforcement pauses were seen at the 30- and 45-sec shelf durations, and the pauses increased when shelf duration was reduced to 5 sec.

Finally, both subjects spent substantial amounts of time on the shelf when it was available. In all conditions in which the shelf was preferred, both subjects were on the shelf 75% or more of the possible time. By comparison, when the shelf was not preferred, *e.g.*, at the 15-sec duration on the ascending series for E3, the amount of time on the shelf fell to low levels.

GENERAL DISCUSSION

In previous studies of timeout from avoidance, subjects were confined to the aversive environment while the shock schedule was suspended (Baron and Trenholme, 1971; Sidman, 1962*b*; Verhave, 1962). The unique feature of the present procedure was that during timeout periods, subjects could escape to a part of the apparatus where shocks never occurred. In general, the results confirmed previous findings by showing the reinforcing properties of timeout. The new finding, observed over a range of experimental manipulations, was that these properties increased substantially when timeout also included opportunity to escape to a safe place. Thus, the shelf-timeout combination increased response rates above baseline avoidance levels with ratios as high as FR 90, and rates declined when the shelf was omitted (Experiment I). Addition of the shelf to timeout in one component of a multiple schedule, but not the other, led to higher response rates in the component where timeout included the shelf (Experiment II). Finally, the shelf-timeout combination was preferred when timeouts with and without the shelf were arranged on equal concurrent schedules (Experiment III).

Interpretation of these findings first requires resolution of the issue of whether the effects do, in fact, reflect the operation of reinforcement mechanisms. As noted earlier, Wahlsten *et al.* (1968) also found that escape from the aversive environment strengthened avoidance

responding, but they and Fantino (1973) attributed this outcome to residual effects of the handling required to replace subjects in the shock chamber. Handling was assumed to disrupt patterns of inactivity ("freezing") that otherwise might interfere with avoidance responding. Similarly, the present results might be attributed to increased activity induced by retraction of the shelf and return of the subject to the grid floor. Such an interpretation, however, falls short on several counts. The shelf contingency influenced running rates more than latencies to the first response of the ratio, whereas effects of shelf retraction should have been greatest at the start of the behavior sequence leading to production of the shelf. Also, preference for the shelf-timeout combination to timeout alone cannot be explained in terms of disruption of freezing, which would not be expected to influence the distribution of responses on the two levers.

The conclusion that the shelf adds to the reinforcing properties of timeout raises the further issue of the source of these properties. Reductions in shock rates do not provide a complete account of the findings. First, *potential* reductions in shock rates were identical, regardless of whether the shelf was present during timeout periods. Nevertheless, subjects responded at higher rates when the shelf was added to timeout. Second, while *actual* reductions in shock rates usually were greater when responding produced the shelf, an analysis attributing increased responding for the shelf to correlated changes in shock rates leaves unanswered the question of what generated such rate increases in the first place. Third, even though choice behavior (relative response rate) could not influence shock rates, the shelf-timeout combination was preferred to timeout alone, to the extent that shorter shelf periods, which provided less reduction in shock rates, were preferred to longer periods of timeout without the shelf. Finally, throughout all three experiments, virtually all subjects, 14 of the 15 studied, persevered in jumping on the shelf when all shocks were cancelled and shock rates could not be influenced.

Although difficult to explain solely in terms of reductions in shock rates, the superior reinforcing properties of the shelf-timeout combination follow from a two-factor interpretation along the lines mentioned in the introductory section of this report. The shelf enabled sub-

jects to escape from stimuli closely associated with the primary aversive event, *e.g.*, stimulation arising from the grid floor, and so increased the amount of reinforcement available during timeout. That subjects jumped on the shelf when it was in the chamber and chose the shelf over longer periods of timeout alone attest to the reinforcing potency of such escape from the aversive environment.

All this is not to say that the present results or their interpretation in terms of two-factor theory argue against the role of shock-rate reduction as *one* factor maintaining avoidance responding or increased responding for timeout. Rather, the results argue for an account that includes control by conditioned forms of reinforcement, in addition to whatever sources of unconditioned negative reinforcement may be present.

The results also bear on interpretations that stress the role of species-specific defense reactions in avoidance learning (Bolles, 1970; 1971). Difficulties in acquisition and maintenance of lever pressing as an avoidance response, by comparison with a running response, for example, have been explained in these terms. But such comparisons must take into account differences in response consequences that accompany different response topographies. Lever pressing, often cited as a response not in the defensive repertory of the rat, changes few, if any of the external stimuli in the subject's environment. The present results, together with those of Wahlsten *et al.* (1968) and Masterson (1970), show that when major environmental changes are contingent on responding, the lever-press response does not place serious limits on avoidance behavior. In the present work, lever pressing showed response patterns typical of fixed-ratio schedules, was brought under stimulus control, and was sensitive to choice contingencies. Throughout, the important controlling variables pertained to response consequences, including the extent to which the lever press terminated stimuli correlated with the aversive event.

The sequence of behavior leading to escape to the shelf can be analyzed as a response chain in which initial lever-press responding produced the shelf and so allowed the terminal response of jumping on the shelf. As is the case with appetitive reinforcers, the initial response in the chain was controlled by the availability of the terminal response. While in gen-

eral there was no correlation between response rates and time spent on the shelf, all but one of the 15 subjects studied spent significant amounts of time on the shelf and responded differentially for the shelf as compared to timeout alone. It also is noteworthy that the only subject that failed to respond differentially for timeout with the shelf also failed to jump on the shelf. An additional finding pointing to the importance of the terminal response was that the procedure of limiting the duration of the shelf to a few seconds, which effectively disallowed jumping, weakened responding to produce the shelf.

By comparison with escape to the shelf, identifying the terminal response in the case of timeout without the shelf is more difficult, but fortunately not essential for the present discussion. Interpreting reinforcement in terms of the strength of the terminal response (*cf.* Premack, 1965), the shelf allowed subjects to engage in behaviors of greater strength than were possible with timeout alone. Such an interpretation is compatible with the two-factor theory of avoidance, which goes on to specify the basis for this difference in strength: jumping onto the shelf more effectively terminated conditioned aversive stimuli or, put another way, provided a safer location. A different way of accounting for this difference in strength is to argue that by comparison with timeout alone, the shelf allowed subjects to engage in behaviors that were demonstrably higher in the hierarchy of innate defense reactions of the rat.

REFERENCES

- Azrin, N. H., Holz, W. C., and Hake, D. F. Intermittent reinforcement by removal of a conditioned aversive stimulus. *Science*, 1962, **136**, 781-782.
- Baron, A. and Trenholme, I. A. Response-dependent and response-independent timeout from an avoidance schedule. *Journal of the Experimental Analysis of Behavior*, 1971, **16**, 123-132.
- Baum, M. An automated apparatus for the avoidance training of rats. *Psychological Reports*, 1965, **16**, 1205-1211.
- Bolles, R. C. Species-specific defense reactions and avoidance learning. *Psychological Review*, 1970, **77**, 32-48.
- Bolles, R. C. Species-specific defense reactions. In F. R. Brush (Ed), *Aversive conditioning and learning*. New York: Academic Press, 1971. Pp. 183-233.
- Denny, M. R. Relaxation theory and experiments. In F. R. Brush (Ed), *Aversive conditioning and learning*. New York: Academic Press, 1971. Pp. 235-295.

- Dinsmoor, J. A. and Sears, G. W. Control of avoidance by a response-produced stimulus. *Learning and Motivation*, 1973, 4, 284-293.
- Fantino, E. Aversive control. In J. A. Nevin (Ed), *The study of behavior*. Glenview, Illinois: Scott, Foresman, 1973. Pp. 239-279.
- Felton, M. and Lyon, D. O. The post-reinforcement pause. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 131-134.
- Hake, D. F. Actual versus potential shock in making shock situations function as negative reinforcers. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 385-404.
- Herrnstein, R. J. Some factors influencing behavior in a two-response situation. *Transactions of the New York Academy of Science*, 1958, 21, 35-45.
- Herrnstein, R. J. Method and theory in the study of avoidance. *Psychological Review*, 1969, 76, 49-69.
- Herrnstein, R. J. and Loveland, D. H. Maximizing and matching on concurrent ratio schedules. *Journal of the Experimental Analysis of Behavior*, 1975, 24, 107-116.
- Masterson, F. A. Is termination of a warning signal an effective reward for the rat? *Journal of Comparative and Physiological Psychology*, 1970, 72, 471-475.
- Mowrer, O. H. A stimulus-response analysis of anxiety and its role as a reinforcing agent. *Psychological Review*, 1939, 46, 553-565.
- Powell, R. W. The effect of small sequential changes in fixed-ratio size upon the post-reinforcement pause. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 589-593.
- Powell, R. W. The effect of reinforcement magnitude upon responding under fixed-ratio schedules. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 605-608.
- Premack, D. Reinforcement theory. In D. Levine (Ed), *Nebraska Symposium on Motivation: 1965*. Lincoln: University of Nebraska Press, 1965. Pp. 123-180.
- Rachlin, H. and Green, L. Commitment, choice, and self-control. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 15-22.
- Rachlin, H. and Herrnstein, R. J. Hedonism revisited: On the negative law of effect. In B. A. Campbell and R. M. Church (Eds), *Punishment and aversive behavior*. New York: Appleton-Century-Crofts, 1969. Pp. 83-109.
- Schoenfeld, W. N. An experimental approach to anxiety, escape, and avoidance behavior. In P. H. Hoch and J. Zubin (Eds), *Anxiety*. New York: Grune and Stratton, 1950. Pp. 70-99.
- Shull, R. L. and Pliskoff, S. S. Changeover behavior under pairs of fixed-ratio and variable-ratio schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1971, 16, 75-80.
- Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning signal. *Science*, 1953, 118, 157-158.
- Sidman, M. Reduction of shock frequency as reinforcement for avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 247-257. (a)
- Sidman, M. Timeout from avoidance as a reinforcer: A study of response interaction. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 423-434. (b)
- Verhave, T. The functional properties of timeout from an avoidance schedule. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 391-421.
- Wahlsten, D., Cole, M., Sharp, D., and Fantino, E. Facilitation of bar-press avoidance by handling during the intertrial interval. *Journal of Comparative and Physiological Psychology*, 1968, 65, 170-175.

Received 17 September 1976.

(Final Acceptance 29 December 1976.)