VARIABLE-INTERVAL SCHEDULES OF TIMEOUT FROM AVOIDANCE

MICHAEL PERONE AND MARK GALIZIO

WEST VIRGINIA UNIVERSITY AND
UNIVERSITY OF NORTH CAROLINA AT WILMINGTON

Rats were trained on concurrent schedules in which pressing one lever postponed shock and pressing the other occasionally produced a 2-min timeout during which the shock-postponement schedule was suspended and its correlated stimuli were removed. Throughout, the shock-postponement schedule maintained proficient levels of avoidance. Nevertheless, in Experiment 1 responding on the timeout lever was established rapidly, was maintained at stable levels on variable-interval schedules, was extinguished by withholding timeout, was reestablished when timeout was reintroduced, and was brought under discriminative control with a multiple variable-interval extinction schedule of timeout. These results are in contrast with Verhave's (1962) conclusion that timeout is an ineffective reinforcer when presented to rats on intermittent schedules. In Experiment 2 the consequence of responding on the timeout lever was altered so that the shock-postponement schedule remained in effect even though the stimulus conditions associated with timeout were produced for 2 min. Responding extinguished, indicating that suspension of the shock-postponement schedule, not stimulus change, was the source of reinforcement. By establishing the reinforcing efficacy of timeout with standard variable-interval schedules, these experiments illustrate a procedure for studying negative reinforcement in the same way as positive reinforcement.

Key words: negative reinforcement, shock-postponement schedule, timeout from avoidance, variable-interval schedules, extinction, multiple schedules, sensory reinforcement, lever press, rats

A central issue in the analysis of aversively controlled behavior is whether negative reinforcement, involving removal, reduction, prevention, or postponement of noxious stimuli, is functionally parallel to positive reinforcement, involving presentation of appetitive stimuli. Experiments have focused on shock avoidance, but use of avoidance as the vehicle to study negative reinforcement may pose both theoretical and procedural difficulties. Whether based on shock-postponement (Sidman, 1953) or shock-deletion (de Villiers, 1972) procedures, avoidance is not well understood and the nature of its reinforcement remains a matter of lively theoretical debate (e.g., Dinsmoor, 1977; Herrnstein, 1969; Hiline, 1981). Procedural matters pose further obstacles. For example, in studies of positive reinforcement, the motivating or estab-

lishing operations—usually defined in terms of food deprivation—can be manipulated independently of the rate or magnitude of the reinforcing stimulus. By comparison, avoidance procedures usually confound these variables: Both motivation and reinforcement are directly related to the rate or intensity of the scheduled shocks. Other procedures are needed to help clarify the nature of negative reinforcement.

Negative reinforcement can be viewed not only in terms of postponement or prevention of primary aversive stimuli occurring within a situation, but also in terms of transitions from one "behavioral situation" to another (Baum, 1973). This view emphasizes the potential aversive function of the avoidance contingency as a whole (DeWaard, Galizio, & Baron, 1979; Hiline, 1981, 1984). Accordingly, the present study arranged negative reinforcement not only through shock postponement, but also through suspension of the shock-postponement schedule. That is, an additional source of negative reinforcement was by "timeout from avoidance."

Only a few studies have investigated timeout from avoidance. Recent experiments arranged conjoint schedules in which respond-

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ing had the dual consequence of avoiding shock and occasionally producing a timeout. Reinforcing functions of timeout were shown by elevations in the rate of a single response when the timeout schedule was superimposed on the avoidance schedule (Baron, DeWaard, & Lipson, 1977; Baron & Trenholme, 1971; DeWaard et al., 1979), by preferential responding on a lever associated with conjoint avoidance and timeout schedules versus a lever with avoidance only (Mellitz, Hineline, Whitehouse, & Laurence, 1983), or by the rate with which three-lever response chains were completed when the chain ended with a timeout (Schrot, Boren, & Moerschbaecher, 1976; Schrot, Boren, Moerschbaecher, & Simoes Fontes, 1978).

Use of conjoint schedules in the above studies places limits on the conclusions that can be reached. A key problem is that of distinguishing between the reinforcing functions of timeout versus those of the avoidance schedule itself. Because both sources of reinforcement contribute simultaneously to response strength, the timeout schedule must be manipulated across conditions or responses to ascertain its relative contribution. Another difficulty is that the influence of one schedule may override or mask aspects of control exerted by the other. For example, in studies in which responding postponed shock and produced timeout on fixed-ratio or fixed-interval schedules, no evidence was found of the pause-and-run patterns usually generated by such schedules (Baron et al., 1977; Baron & Trenholme, 1971), possibly because the shock-postponement schedule encouraged steady rates. The general concern raised by these problems is that when timeout schedules are arranged conjointly with avoidance, it may not be possible to compare directly the effects of negative reinforcement with those of positive reinforcement.

An alternative strategy is to arrange concurrent schedules in which avoidance and timeout are contingent on separate responses. In an early series of experiments, Verhave (1962) investigated such a procedure with rats and found that responding on the timeout lever was difficult to maintain on intermittent schedules. On fixed-ratio schedules, responding was maintained only when the ratio was small, and on fixed-interval schedules, responding was minimal with no positive accel-

eration within the interval. These findings led Verhave to conclude that, with rats at least, the reinforcing functions of timeout are weak compared to those of conventional appetitive stimuli such as food. Perhaps this early conclusion is responsible for later investigators' reliance on conjoint schedules to study timeout, as well as for the relative lack of interest in timeout as a means of investigating negative reinforcement.

Verhave may have been unduly pessimistic about the reinforcing potency of timeout from avoidance. Experiments with primates have been successful in maintaining behavior on independent fixed-ratio (Sidman, 1962) and fixed-interval (Findley & Ames, 1965) schedules of timeout. More recently, rats' responding has been maintained on progressive-ratio schedules of timeout, with pause-and-run patterns comparable to those observed with food reinforcement (Posner & Baron, 1981).

The present research also studied timeout from avoidance by using procedures in which an isolated response had timeout as its sole consequence. On concurrent schedules, rats' presses on one lever postponed shock while presses on a second lever occasionally removed the shock-postponement schedule (and the stimuli correlated with it) for 2 min. This arrangement was used to explore the possibility of studying negative reinforcement by scheduling timeout in basically the same way as positive reinforcers.

EXPERIMENT 1

The first experiment addressed Verhave's (1962) reservations about the reinforcing strength of timeout. Although there are no standard tests to assess the adequacy of a stimulus event as reinforcer, an informal survey of experimental practice suggests some basic criteria. An adequate reinforcer should allow a researcher to establish behavior rapidly, maintain it at stable levels over extended numbers of sessions, and bring it under stimulus control by differential reinforcement and extinction. Experiment 1 was designed to determine whether timeout from avoidance could pass these tests. While rats' presses on one lever avoided shock, presses on another produced timeout according to multiple schedules with variable-interval and extinction components.

METHOD

Subjects

Four male Sprague-Dawley rats (Holtzman Co.), about 60 days old at the start, were housed in individual cages under continuous lighting with free access to food and water. A fifth rat served in the early phases, but was discarded because it tended to hold the avoidance lever and this prevented contact with the schedule of timeout programmed on the other lever.

Apparatus

The rats were trained in a custom-built chamber, approximately 29 cm long, 22 cm wide, and 29 cm high, enclosed within a sound-attenuating, ventilated chest. The side walls and ceiling were constructed of Plexiglas, the end walls of aluminum, and the floor of stainless steel rods 1.6 mm in diameter spaced 1.3 cm apart, center-to-center. Illumination was provided by a 6-W lamp mounted behind translucent white plastic on a side wall. A constant-current shock generator (Grason-Stadler, E1064GS) delivered scrambled shocks (1 mA, 0.5 s) to the grid floor. White noise of 80 dB (with episodic increases to 85 dB during experimental procedures) was supplied through a speaker mounted behind the front wall. Two retractable levers (BRS/LVE, RRL-015) were centered 13 cm apart on the front wall, 11 cm above the grid floor. Each lever required a force of approximately 0.3 N to operate. Response feedback was provided by turning off the white noise for 0.25 s after presses on the right lever (avoidance lever), and by an audible relay click after presses on the left (timeout lever). Electromechanical programming and recording equipment was in an adjacent room.

Preliminary Training

Initial phases were designed to (a) shape avoidance; (b) provide exposure to timeout conditions during which the avoidance contingency was temporarily suspended; and (c) develop and maintain lever pressing by an intermittent schedule of timeout. Sessions were conducted on alternate days and usually lasted 4.5 hr.

Avoidance. With the left lever retracted, the rats were trained to press the right lever, us-

ing a shock-postponement procedure. Lever pressing was shaped in a single 1-hr session and then was maintained by a schedule in which each response postponed shock for 30 s (the response-shock or RS interval), but in the absence of responding, shocks were presented every 5 s or, in the case of Rat T2, 30 s (the shock-shock or SS interval). Training continued for a total of 13 hr, during which the session length was gradually increased to 4.5 hr.

Response-independent timeout. To give the rats exposure to timeout conditions, three 10-min timeout periods were scheduled during each session, approximately 83, 145, and 208 min after its beginning. During a timeout, the shock-postponement schedule was suspended and the stimulus conditions were identical to those prevailing before and after a session: The lever was retracted and the houselight and white noise were turned off. At the end of a timeout, the shock-postponement schedule was reset to the beginning of the RS interval. Training continued for 6 to 12 sessions.

Response-dependent timeout. Sessions in this phase began with a 30-min warmup period involving only the right lever and shock-postponement schedule, after which the left lever and timeout schedule were added. Initially, each left-lever press produced a 5-min timeout. Stimulus changes accompanying timeout were the same as in the previous condition, but in addition the left lever was retracted (this lever had not been inserted before). Each of the 4 rats pressed the timeout lever during its first session, without experimenter intervention. After consistent responding was observed, the duration of the timeout was gradually reduced, reaching 2 min by the end of the second session. Thereafter, the timeouts were presented according to a variable-interval (VI) schedule (Fleshler & Hoffman, 1962), with the mean interval gradually increased over the next three to six sessions, from 15 s to a terminal value of 45 s. The concurrent schedules of avoidance and timeout from avoidance were continued for 16 to 31 sessions, until timeout response rates were stable (see stability criteria below) and at least 75% of the scheduled RS shocks were avoided.

Procedure

During the remainder of the experiment, right-lever presses postponed shock and left-

Table 1

Experiment 1: Summary of conditions, response rates, shock rates, percentage of RS shocks avoided, and rates of timeout production. Data are means of the last 10 sessions, separated by component of the multiple schedule on the timeout lever. "S1" and "S2" designate the multiple-schedule components. Standard deviations are in parentheses.

Rat	Timeout schedule	Sessions	Avoid. resp./min		Shocks/min		% RS avoided		Timeout resp./min		Timeouts/min	
			S1	S2	S1	S2	S1	S2	S1	S2	S1	S2
T1	Mult VI VI	10	6.5 (0.9)	7.8 (1.0)	0.27 (0.20)	0.30 (0.33)	90 (8)	92 (9)	2.9 (0.5)	3.7 (0.8)	0.94 (0.09)	1.04 (0.15)
	Mult VI EXT	25	6.1 (0.8)	6.5 (0.7)	0.08 (0.06)	0.15 (0.09)	96 (3)	94 (3)	2.1 (0.3)	0.1 (0.1)	0.89 (0.09)	—
	Mult VI EXT ^a	11	4.6 (0.3)	4.7 (0.3)	0.35 (0.13)	0.15 (0.04)	85 (6)	94 (2)	2.0 (0.4)	0.1 (0.1)	0.82 (0.07)	—
	Mult VI EXT	11	5.3 (0.8)	4.9 (0.9)	0.05 (0.04)	0.05 (0.04)	97 (2)	98 (2)	2.2 (0.3)	0.0 (0.0)	0.86 (0.08)	—
	Mult VI VI	19	4.7 (0.5)	4.5 (0.4)	0.19 (0.12)	0.14 (0.10)	92 (4)	95 (3)	2.3 (0.4)	2.5 (0.2)	0.94 (0.11)	0.97 (0.08)
T2	Mult VI VI	10	9.3 (1.0)	9.8 (0.9)	0.01 (0.01)	0.02 (0.02)	100 (1)	99 (1)	6.7 (0.9)	7.3 (1.0)	0.99 (0.11)	1.01 (0.06)
	Mult VI EXT	21	7.7 (0.7)	6.1 (0.4)	0.01 (0.02)	0.02 (0.02)	99 (1)	99 (1)	6.4 (0.7)	1.1 (0.5)	0.96 (0.12)	—
	Mult VI EXT ^a	16	6.2 (0.6)	6.1 (0.4)	0.02 (0.03)	0.02 (0.01)	99 (1)	99 (1)	6.0 (0.8)	0.2 (0.1)	0.96 (0.06)	—
	Mult VI EXT	30	4.2 (0.4)	4.5 (0.5)	0.02 (0.02)	0.03 (0.03)	99 (1)	99 (1)	5.1 (1.2)	0.2 (0.2)	1.02 (0.11)	—
	Mult VI VI	17	3.5 (0.2)	3.8 (0.3)	0.04 (0.02)	0.02 (0.03)	98 (1)	99 (1)	4.4 (0.7)	4.5 (0.7)	0.95 (0.14)	0.91 (0.12)
T3	Mult VI VI	10	6.4 (1.1)	5.6 (0.9)	0.59 (0.29)	0.51 (0.30)	87 (5)	89 (7)	6.0 (1.3)	7.4 (1.1)	1.09 (0.07)	1.09 (0.07)
	Mult VI EXT	18	5.3 (0.7)	4.2 (0.4)	0.21 (0.13)	0.43 (0.23)	94 (3)	88 (5)	7.4 (1.0)	1.3 (0.4)	1.13 (0.10)	—
	Mult VI EXT ^a	10	4.9 (0.5)	5.2 (0.8)	0.33 (0.25)	0.59 (0.15)	88 (10)	84 (6)	7.1 (1.0)	0.3 (0.2)	1.10 (0.13)	—
	Mult VI EXT	31	4.7 (0.7)	7.8 (0.9)	0.35 (0.19)	0.46 (0.21)	85 (7)	84 (6)	4.8 (0.5)	0.4 (0.4)	1.01 (0.07)	—
	Mult VI EXT ^a	25	3.8 (0.5)	7.4 (0.4)	0.14 (0.03)	0.35 (0.06)	94 (2)	87 (2)	6.6 (0.5)	0.1 (0.1)	1.00 (0.06)	—
	Mult VI VI ^a	22	2.8 (0.3)	2.6 (0.2)	0.52 (0.20)	0.73 (0.20)	85 (6)	78 (5)	3.7 (0.3)	3.4 (0.3)	1.04 (0.11)	0.98 (0.03)
T5	Mult VI VI	13	4.0 (0.2)	3.9 (0.6)	0.16 (0.08)	0.17 (0.11)	96 (2)	95 (3)	4.1 (0.7)	4.3 (0.7)	1.10 (0.11)	1.03 (0.08)
	Mult VI EXT	15	3.9 (0.4)	3.8 (0.4)	0.09 (0.06)	0.24 (0.10)	97 (2)	92 (3)	5.3 (0.6)	0.5 (0.4)	1.10 (0.09)	—
	Mult VI EXT ^a	15	4.3 (0.4)	4.0 (0.1)	0.11 (0.05)	0.48 (0.10)	97 (2)	86 (3)	7.1 (0.8)	0.1 (0.0)	1.12 (0.12)	—

^a S2 component lasted 30 min.

lever presses occasionally produced 2-min timeouts. While a session was in progress, both levers were inserted, the chamber was illuminated with either constant or flashing light, and white noise was present. During a timeout (as well as before and after a session), both levers were retracted, the schedules were suspended, the chamber was darkened, and the noise was removed. When the session re-

sumed, the shock-postponement schedule was reset to the start of the RS interval. Throughout the experiment, the avoidance-schedule parameters were constant, with an RS interval of 30 s and an SS interval of either 5 s (Rats T1, T3, and T5) or 30 s (T2).

With regard to the timeout schedule, the sessions were divided into two alternating components (S1 and S2), differentiated by

compound stimuli. For Rats T1 and T2, the S1 component was accompanied by constant illumination and 80-dB white noise, whereas S2 was accompanied by a flashing houselight and 85-dB noise. The stimuli were reversed for Rats T3 and T5. The VI 45-s schedule of timeout always was programmed in the S1 component. To study development of schedule control and stimulus control of timeout-reinforced responding, and to assess the possibility of multiple-schedule interactions, the VI schedule was alternated with extinction (EXT) in the S2 component.

Table 1 summarizes the conditions. After a baseline in which the VI schedule of timeout was programmed in both components, extinction was programmed during S2, so that presses on the timeout lever were ineffective in the presence of that stimulus. To promote discrimination between the components, a "correction procedure" prevented onset of the VI component within 1 min of a response on the timeout lever during extinction. Component presentations during these first two conditions were programmed to last 6 min (exclusive of timeout periods), and were alternated until there were five presentations of each (sessions always started with S2). In the next condition, the EXT component was increased to 30 min. Rat T5 died after completing this condition. The remaining rats served in a replication of the multiple VI EXT condition with 6-min components. Then 2 rats (T1, T2) were returned to the multiple VI VI baseline. The other rat (T3) was studied again under the multiple VI EXT schedule with 30-min EXT components before being returned to the multiple VI VI condition. In this last condition for Rat T3, the second component (S2) was 30 min long, the same length as the S2 component in the prior multiple VI EXT condition, and sessions terminated after three presentations of S1 and S2 instead of five.

As during preliminary training, sessions were conducted on alternate days. Conditions were changed when response rates on the timeout lever were stable over 10 sessions. The stability criterion required that the difference between the means of the first five and last five sessions be within 15% of the grand mean. Exceptions were made during the multiple VI EXT conditions, when the criterion was not applied to rates in the EXT component.

Sessions were preceded by a two-part

warmup period. In the first part the white noise (80 dB) was on and the houselight off, only the right lever was inserted, and the shock-postponement schedule was programmed for 30 min. In the second part the left lever and VI timeout schedule were added for 6 min (exclusive of timeout periods), accompanied by the S1 stimulus. Data collection began at the end of this warmup period.

RESULTS

Table 1 shows the data averaged across the last 10 sessions of each condition. Comparisons of responding maintained by the concurrent schedules of avoidance and timeout can be made by considering data from the components in which both responses were reinforced. This occurred in a total of 19 cases shown in Table 1 (i.e., in the S1 and S2 components when the timeout schedule was multiple VI VI and in S1 when it was multiple VI EXT). Lever-press rates were moderate, ranging from about 3 to 10 responses per min on the avoidance lever and about 2 to 7 on the timeout lever (during VI components). The two sets of rates were roughly equivalent for three of the rats (T2, T3, T5), although timeout rates tended to be slightly higher. (Timeout means exceed avoidance means in 14 of 19 components in which both responses were reinforced.) The exception was T1, whose timeout rates were consistently lower than its avoidance rates. The consequences of responding were that shocks occurred rarely and timeouts occurred frequently. With few exceptions, more than 85% of the potential RS shocks were avoided¹ (considering only time-in periods when the shock-postponement schedule was operative). Timeouts were produced at an average rate of about one per minute, 75% of the maximum possible on the VI 45-s schedule.

Rates of pressing the timeout lever are

¹ The avoidance index was based on the RS interval because this part of the shock-postponement schedule was operative during most of the session, and because the index accurately reflects the extent to which subjects actively avoided shock. A rat that merely held the response lever and depressed it reflexively with each shock would receive RS shocks at the maximum possible rate of 2 per min (with RS = 30 s). By the present index, that avoidance rate would be zero. In contrast, if the index were based on the SS interval (5 s), such a performance would appear to be efficient avoidance, for the obtained shock rate of 2 per min would be substantially below the potential rate of 12 per min arranged by the SS interval of the schedule.

Fig. 1. Experiment 1: Responses per min on the timeout lever during the two components (S1, S2) of the multiple VI VI and multiple VI EXT schedules of timeout from avoidance, for each of 4 rats. In the multiple VI EXT conditions, S2 was the EXT component. Unless otherwise noted, component durations were 6 min (exclusive of timeout periods). Data are presented from all sessions in the first multiple VI EXT and final multiple VI VI conditions; otherwise the data are from the last 10 sessions of a given condition.

shown on a session-by-session basis in Figure 1. Data are presented from all sessions in the first multiple VI EXT and final multiple VI VI conditions; otherwise the data are from the last 10 sessions of each condition. Response rates were relatively stable from session to session within each condition. Rates in the two schedule components were undifferentiated under the multiple VI VI baseline (Panel 1 of Figure 1), but under the multiple VI EXT procedure discriminative stimulus control developed rapidly, as rates declined to nearly zero in the EXT component while remaining

essentially unchanged in the VI component (Panel 2).

Manipulating the duration of the EXT component did not affect the VI rates of two of the rats (T1, T2; see Panels 2–4). For the third rat (T3), no effect was apparent when the component was originally increased from 6 to 30 min (compare Panels 2 and 3). However, reducing the EXT component back to 6 min lowered T3's VI rates and produced greater variability in EXT rates (Panel 4); a return to the 30-min component reversed these effects (Panel 5). The last rat (T5) may also

have been affected by the EXT duration, as suggested by the increased VI rates seen in the third panel of Figure 1. Unfortunately, the death of this animal precluded further study.

Finally, the multiple VI VI schedule was reinstated. Rates in the second component recovered rapidly, reaching asymptotic levels within six sessions. By the end of training, rates in the two components were again undifferentiated. In addition, T3's rates on the timeout lever were clearly below the VI rates observed in the multiple VI EXT conditions.

Cumulative records of one rat's responses on the timeout and avoidance levers are presented in Figure 2. The records are taken from the last (10th) session of the multiple VI VI baseline and the first, middle (11th), and last (21st) sessions of the initial multiple VI EXT condition. The upper records show responding on the timeout lever. The recorder motor ran only when the schedule was operative, stopping during timeout periods when the lever was retracted. Pips on the records indicate the onset of these periods. The response pen was downset during presentations of the S2 component. A common feature apparent in all of the records is considerable variability in the interresponse times, with shorter times tending to occur during the "leaner" parts of the VI schedule, as in the portions of Record 1 labeled "a," "b," and "c." During early exposure to the EXT component (Record 2), responding persisted and, because of the correction procedure, this had the effect of prolonging the component until 1 min had elapsed without a response. By the 11th session, rates in the VI and EXT components were well differentiated (Record 3), and little change is apparent between performances in this session and the last one of the condition (Record 4).

The lower records in Figure 2 show concurrent responding on the avoidance lever. The recorder operated as described above, except that pips designate shocks (which were received rarely). Although variation in interresponse time is not as great as with the timeout lever, brief pauses and response bursts add a grained texture to the records. This pattern occurred only when avoidance was in competition with timeout-reinforced responding—that is, when a VI schedule of timeout was in effect

on the other lever (as in all of Record 1 and in alternate components of Records 2–4). In components when responding could not produce timeout, avoidance responding was steadier (see especially Records 3 and 4), presumably because the rat no longer alternated between the two levers.

DISCUSSION

Overall, the results of Experiment 1 show that rats' responding on VI schedules of timeout from avoidance resembles responding on analogous schedules of food reinforcement. With timeout as its sole consequence, responding was rapidly acquired, maintained at steady-state on intermittent schedules and, after extinction by withholding timeout, reacquired. Stimulus control was readily established under a multiple VI EXT schedule. Interaction between the components of the multiple schedule was not consistently observed. Two rats showed some evidence of positive behavioral contrast when the EXT component was lengthened to 30 min, but two others showed no effect—neither contrast nor induction. Although the reason for failing to replicate contrast effects across subjects cannot be specified, it should be noted that such inconsistency has been widely reported in studies using more conventional reinforcement procedures with rats (Schwartz & Gamzu, 1977).

The present results show that timeout can be an effective, durable reinforcer when made available to rats through interval schedules. As such, the results differ from those of Verhave (1962), who found that timeout did not sustain much behavior on intermittent schedules. Two procedural differences probably contributed to the contrasting outcomes. First, Verhave used an arbitrary stimulus (a tone) to signal the timeout periods, whereas we used the withdrawal of the discriminative stimuli controlling avoidance responding. Thus, the stimulus conditions accompanying the within-session timeouts in our experiment were the same as those prevailing before and after the sessions. Second, Verhave programmed timeouts on fixed-ratio and fixed-interval schedules, whereas we used a VI schedule. An important characteristic of VI schedules is their ability to "regenerate" responding when it weakens; that is, the schedules tend to make

Fig. 2. Experiment 1: Cumulative response records for Rat T2 during the last session of the multiple VI VI baseline (Record 1), and the first, 11th, and last (21st) sessions of the initial multiple VI EXT condition (Records 2 to 4). The response pen was downset during the S2 component, and the recorder motor was stopped during timeout periods while the response levers were retracted. In the upper records (timeout lever) pips indicate timeout reinforcers; "a," "b," and "c" designate lean portions of the VI timeout schedule during which shorter interresponse times were observed. In the lower records (avoidance lever) pips indicate shocks. In both cases Record 2 does not show the entire session, which was prolonged considerably by timeout responses during the EXT component.

the reinforcer available when interresponse times grow longer (Zeiler, 1977). This characteristic may be especially important when the timeout schedule competes with a concurrent shock-postponement schedule that forces steady rates of avoidance responding. By comparison with VI schedules, ratio schedules reduce local reinforcement rates when interresponse times lengthen, leading to further reductions in response strength. Although fixed-interval schedules do allow response-regenerating effects to occur, the long intervals in Verhave's experiments (5–15 min)—especially in relation to the short RS interval of his shock-postponement schedule (30 s)—probably minimized the effects.

EXPERIMENT 2

In the first experiment responding on the timeout lever was maintained by occasional suspension of the shock-postponement schedule and removal of the stimuli correlated with it, and responding extinguished when these consequences were withheld. One interpretation emphasizes negative reinforcement of responding by suspension of the avoidance contingency, but it is possible that responding was maintained by the accompanying stimulus changes. The second experiment examined this possibility. Baseline responding produced 2-min timeouts according to a VI schedule. Subsequently, the timeouts were replaced by "sham-timeout" periods during which the stimulus changes usually correlated with timeout were arranged for 2 min but the shock-postponement schedule was not suspended. Of interest was whether responding on the timeout lever would extinguish under such conditions.

METHOD

Subjects

Four male Sprague-Dawley rats, born and raised in the laboratory colony, were about 15 months old at the start of the present experiment. In prior research they had received extensive experience with concurrent schedules of avoidance and timeout, and had been exposed to a range of doses of ethanol and naloxone (Galizio, Perone, & Spencer, 1986). Housing conditions were the same as in Experiment 1.

Apparatus

Training took place in commercially constructed chambers, approximately 30 cm long, 21 cm wide, and 19 cm high, enclosed in sound-attenuating, ventilated chests (Lehigh Valley, 1316 and 1316C). The side walls and ceiling were constructed of Plexiglas, the end walls of stainless steel, and the floor of stainless steel rods 0.5 cm in diameter spaced 1.9 cm apart, center-to-center. Illumination was provided by a 7.6-W bulb mounted behind a white sheet of paper on a side wall. A constant-current shock generator and scrambler (Lafayette, 82400-SS and 58020) delivered 1-mA, 0.5-s shocks to the grid floor. White noise (80 dB) was supplied through a speaker mounted in the chest. Two levers were centered 10 cm apart on the front wall, 9 cm above the floor. The right lever (avoidance lever) was fixed in place; the left lever (timeout lever) was retractable. Response-force requirements and feedback were as in Experiment 1, except the offset of white noise following avoidance responses lasted 0.5 s rather than 0.25 s. Control and recording operations were accomplished with a microcomputer (Tandy, TRS-80® Model III) connected to the chambers by a commercial interface (Alpha, Interfacer 80) and electro-mechanical components, using software described elsewhere (Perone, 1985).

Procedure

Throughout the experiment, right-lever presses postponed shock on a schedule with RS and SS intervals of 30 s and 5 s, respectively. The consequence of pressing the left lever was manipulated in two conditions that alternated across blocks of sessions as summarized in Table 2.

In the timeout condition, left-lever presses produced 2-min timeouts according to a VI 45-s schedule. While the concurrent timeout and avoidance schedules were under way, both levers were inserted, the chamber was illuminated, and white noise was present. The schedules were suspended during a timeout, during which the timeout-producing lever was retracted, the chamber was darkened, and the white noise was removed. The avoidance lever remained in place during the timeouts and presses on it were recorded, but they had no scheduled consequences.

In the sham-timeout condition, the conse-

Table 2

Experiment 2: Summary of conditions, response rates, shock rates, percentage of RS shocks avoided, and rates of timeout and sham-timeout production. Data are means of the last 10 sessions, with standard deviations in parentheses.

Rat	Condition	Sessions	Avoid. resp./min		Shocks/min		% RS avoided		Time- out resp./ min	Time- outs ^a per min
			Time- in	Time- out ^a	Time- in	Time- out ^a	Time- in	Time- out ^a		
X1	Timeout	10	3.9 (0.5)	0.0 (0.0)	0.36 (0.47)	—	95 (1)	—	3.0 (0.3)	1.00 (0.06)
	Sham-Timeout	20	6.2 (0.9)	5.2 (1.0)	0.12 (0.06)	0.75 (0.25)	95 (3)	73 (8)	0.2 (0.2)	0.16 (0.10)
	Timeout	16	4.2 (0.5)	0.1 (0.1)	0.25 (0.23)	—	93 (4)	—	3.3 (0.4)	1.02 (0.06)
	Sham-Timeout	20	6.7 (1.2)	5.3 (0.9)	0.22 (0.25)	0.44 (0.16)	93 (5)	84 (4)	1.3 (0.7)	0.53 (0.21)
	Timeout	16	2.9 (0.7)	0.1 (0.1)	0.94 (0.66)	—	81 (11)	—	3.5 (1.3)	1.05 (0.08)
Y1	Timeout	10	13.0 (2.3)	0.1 (0.2)	0.01 ^b (0.01)	—	100 ^b (0)	—	2.8 (0.7)	0.94 (0.08)
	Sham-Timeout	20	11.7 (1.4)	7.0 (0.9)	0.02 (0.01)	0.06 (0.05)	99 (1)	98 (2)	0.8 (0.2)	0.51 (0.09)
	Timeout	16	8.1 (0.6)	0.1 (0.3)	0.04 (0.04)	—	98 (2)	—	2.6 (0.5)	0.96 (0.06)
	Sham-Timeout	20	10.3 (1.2)	7.3 (1.3)	0.04 (0.03)	0.10 (0.06)	98 (1)	95 (2)	0.6 (0.3)	0.42 (0.11)
	Timeout	16	6.4 (0.5)	0.2 (0.1)	0.18 (0.07)	—	92 (3)	—	3.1 (0.7)	0.97 (0.09)
X2	Timeout	10	5.0 (0.6)	0.0 (0.0)	0.19 (0.16)	—	92 (7)	—	5.9 (0.7)	1.15 (0.07)
	Sham-Timeout	20	7.0 (1.1)	5.9 (0.8)	0.04 (0.03)	0.15 (0.06)	98 (1)	93 (3)	0.3 (0.2)	0.19 (0.10)
	Timeout	16	4.0 (0.4)	0.0 (0.0)	0.25 (0.10)	—	89 (4)	—	4.9 (0.5)	1.11 (0.06)
Y2	Timeout	10	4.8 (0.6)	0.0 (0.0)	0.06 (0.02)	—	97 (2)	—	1.9 (0.3)	0.84 (0.10)
	Sham-Timeout	20	7.0 (0.6)	6.0 (0.7)	0.04 (0.02)	0.18 (0.08)	98 (1)	92 (3)	0.4 (0.2)	0.19 (0.12)
	Timeout	21	5.6 (0.7)	0.2 (0.1)	0.09 (0.05)	—	96 (2)	—	3.5 (0.6)	1.02 (0.08)

^a Or sham-timeouts, depending on the condition.

^b The apparent discrepancy between shock rate and avoidance rate in this case is an artifact of rounding.

quence of pressing the timeout lever was altered so that the shock-postponement schedule remained in effect even though the timeout lever, chamber illumination, and white noise were removed for 2 min. Thus, during these sham-timeout periods shocks occurred unless they were postponed by presses on the avoidance lever. The sham-timeouts were produced according to the same VI 45-s schedule used during the timeout condition.

Sessions usually were conducted 6 days per week and lasted 100 min. They were preceded

by a 20-min warmup period. Unlike the first experiment, the concurrent schedules were operative throughout the daily procedure, including both the warmup period and the session proper. Conditions were changed when it was apparent by visual inspection whether the procedures maintained responding on the timeout lever.

RESULTS

Table 2 presents the average data for the last 10 sessions of each condition. In the time-

Fig. 3. Experiment 2: Cumulative response records from timeout and sham-timeout conditions for Rat X2. The response pen stepped upward with avoidance responses, deflected momentarily with shocks, and was downset during timeouts (upper and lower records) or sham-timeouts (middle record). The event pen deflected with responses on the timeout lever. The avoidance lever remained in the chamber during timeouts and sham-timeouts, but the timeout lever was retracted. Arrows indicate the end of the 20-min warmup period and the start of the 100-min session proper.

out conditions, stable lever pressing was maintained by both the shock-postponement and timeout schedules, with rates that ranged from about 3 to 13 responses per minute on the avoidance lever and from about 2 to 6 on the timeout lever. Although in the first experiment timeout rates tended to exceed avoidance rates slightly, in the present experiment the two sets of rates were either about equal (Rats X1, X2) or timeout rates were lower (Y1, Y2). Percentage of RS shocks avoided (usually 90% or more) and timeout production rates (about one per minute) were similar to those in Experiment 1.

The effects of replacing the timeout periods with sham-timeouts during which the shock-postponement schedule was left in force are illustrated in Figure 3. The figure shows cumulative records from 3 days of testing for Rat X2, and includes both the warmup period and the session proper. The start of the session is designated by an arrow. In each record, the upper pen stepped with avoidance responses,

deflected momentarily with shock presentations, and downset during the 2-min timeouts or sham-timeouts. The lower pen deflected with timeout responses. Unlike Experiment 1, the recorder motor continued to operate during the timeouts (and sham-timeouts) because the avoidance lever remained in the chamber during these periods (the timeout lever was retracted, however).

The top record, from the last day under the baseline condition, shows the typical performances engendered by the concurrent schedules of avoidance and timeout. When the schedules were in progress (time-in), responding was distributed between the two levers, virtually all shocks were avoided, and timeouts were produced frequently. When a timeout was in progress, the rat almost never pressed the avoidance lever. Thus, avoidance responding was under sharp discriminative control by the stimuli correlated with timeout and time-in.

The middle record is from the last day un-

der the sham condition. Responding occurred almost exclusively on the avoidance lever, and local rates were above baseline levels. The rat rarely produced the sham-timeouts, but when it did, it continued to press the avoidance lever (albeit less effectively than during time-in periods), showing loss of discriminative control by the stimuli previously correlated with timeout.

The bottom record is from a late session in the replication of the timeout condition. The response patterns closely resemble those observed under the original baseline.

Session-by-session response rates on the two levers are shown for all of the rats in Figure 4, which is based on data from the time-in portions of each 100-min session. On the left lever (unfilled circles), stable rates were maintained when the consequence was timeout, but not when it was sham-timeout. In the first exposure to the sham condition (Panel 2), rates dropped below one per minute within three to six sessions and remained at that level for the rest of the condition (see Table 2 for a summary of terminal rates). Reinstatement of the timeout condition (Panel 3) led to recovery of responding within three sessions for all but Rat Y2, which required nine sessions. Replication of the sham condition (Rats X1, Y1; Panel 4) also produced rapid reductions in responding, although in later sessions X1's rates increased somewhat. Again, rates recovered upon reinstatement of the timeout contingency.

On the right lever, avoidance responding (filled circles) was maintained throughout the experiment. During sham conditions, however, rates were elevated compared to timeout conditions. In X2 and Y2, the enhanced avoidance rates appeared early in the first sham condition and then dissipated somewhat in later sessions. However, these rats' terminal rates were still above the levels observed in the timeout conditions studied before and afterwards (compare Panels 1 and 3 with Panel 2; also see Table 2 for a summary of terminal rates). Different session-to-session patterns can be seen in the other rats. For X1, elevated rates were maintained throughout the first sham condition, but rates declined slightly in the late sessions of the second exposure. For Y1, no elevation can be seen in the first sham condition, but reinstatement of the timeout contingency reduced baseline levels of re-

sponding. By comparison with these levels, avoidance rates in the second sham condition were elevated (compare Panel 4 with Panels 3 and 5). Thus, sham conditions clearly raised avoidance rates in 3 of the rats, and in the fourth (Y1) the effect appeared in the second exposure.

DISCUSSION

The major finding of Experiment 2 was that pressing the timeout lever was reinforced when it occasionally suspended the avoidance contingency for 2 min (timeout), but pressing extinguished when it merely produced a change in the prevailing stimulus conditions (sham-timeout). This finding indicates that response-contingent suspension of the avoidance contingency, not stimulus change, was responsible for maintaining responding on the timeout lever.

An additional finding was that when timeout responding extinguished, avoidance responding increased in at least 3 of 4 rats. Although the present experiment was not designed to isolate the variables controlling variations in avoidance, several possible accounts are worth considering. First, the relationship between responding on the two levers could be characterized as "concurrent behavioral contrast," because the rate of avoidance responding was inversely related to the rate of reinforcement for the concurrently available timeout response (cf. Rachlin, 1973). This interpretation is attractive because it suggests that a phenomenon associated with concurrent schedules of positive reinforcement (e.g., Catania, 1961; Norman & McSweeney, 1978) also can be observed with negative reinforcement. The elevated avoidance rates need not reflect concurrent-schedule interactions, however. If elevated rates result from extinction of concurrent timeout responding, then elevations should have been observed in Experiment 1 when extinction was programmed in one component of the multiple timeout schedule. When the S2 component of that schedule was changed from VI to EXT, S2 avoidance rates should have increased (as timeout rates decreased), and when the schedule was returned to VI, avoidance rates should have decreased (as the timeout rates increased). The average S2 avoidance rates in Table 1 do not fit such a pattern, however, and inspection of daily avoidance rates (not shown) revealed no

Fig. 4. Experiment 2: Responses per min on the avoidance and timeout levers, for each of 4 rats. Rates are based on the time-in portions of the 100-min sessions, when both responses were available concurrently.

systematic differences as a function of the concurrent timeout schedule in 3 of the 4 rats. An exception was Rat T3 during the last two multiple VI EXT conditions, when its S2 avoidance rates rose above earlier levels (as well as above levels in the S1 component in which the timeout response was reinforced). The failure to observe reliable increases in avoidance rates when timeout responding was

extinguished in Experiment 1 suggests that the increases observed in Experiment 2 should not be interpreted as concurrent-schedule interactions.

Other accounts can be formulated solely on the basis of the contingencies involving the avoidance response—that is, without regard to the concurrent timeout schedule. One possibility is that the increased avoidance rates

during time-in are related to the higher shock rates that occurred during the alternating sham-timeout periods. (As Table 2 shows, avoidance proficiency during sham-timeouts was not as great as during time-in.) Arguing against this interpretation is the lack of a consistent relationship between the sham-timeout shock rates (Table 2) and the elevated avoidance rates during the time-in periods (Table 2 and Figure 4).

Perhaps the most straightforward view would be to consider the avoidance contingency in the timeout condition as a multiple schedule with alternating avoidance and timeout components, and to consider it as two alternating avoidance components in the sham condition. Previous research has shown that responding on an avoidance schedule is reduced when the schedule alternates with a timeout component (Appel, 1960). In the present experiment the shift from timeout to sham conditions may have been functionally equivalent to a shift from multiple avoidance-timeout to multiple avoidance-avoidance. Regarded in this light, the elevated avoidance rates in the latter condition would reflect interactions between the components of a multiple schedule of avoidance, rather than interactions between the concurrent schedules of avoidance and timeout.

GENERAL DISCUSSION

Previous demonstrations of negative reinforcement by timeout from avoidance have relied on procedures differing from those used most often in analyses of positive reinforcement. In studies with rats, intermittent schedules of timeout have been effective in maintaining behavior when an interval schedule is superimposed on an avoidance schedule (e.g., Baron & Trenholme, 1971) or when a ratio schedule initially arranges timeout on a continuous basis and then progressively increases the response requirement over the course of the session (Posner & Baron, 1981). By comparison, in the present research timeout was the sole consequence of responding that was maintained throughout the session on standard VI schedules.

The reinforcing effectiveness of timeout was shown in several ways. Of 9 rats starting the experiments, only 1 failed to develop responding, and this failure can be attributed to lack

of contact with the timeout contingency—the rat simply did not venture away from the avoidance lever. For the rats that did contact the contingency, acquisition was rapid and stable responding was maintained on simple and multiple VI schedules. Responding extinguished when timeouts were withheld or when only stimulus change resulted, but reacquisition was rapid when the timeout contingency was reinstated. Discriminative stimulus control developed under multiple VI EXT schedules of timeout.

One aspect of the present findings has potential for generating confusion about the potency of timeout as a reinforcer. Because mean rates of timeout production were only 70% to 85% of the maximum allowed by the VI 45-s schedule, one might infer that timeout is a relatively weak reinforcer by comparison with more conventional ones such as food. The validity of this inference depends on the assumption that obtained reinforcement rates are likely to be maximal when the reinforcer is food. This assumption is doubtful when, as in the present experiment, responding is controlled by two concurrent, and competing, schedules of reinforcement. Relevant data are provided by a study of rats' lever pressing on concurrent VI schedules, with standard 45-mg food pellets as the reinforcers (Norman & McSweeney, 1978). Reinforcement rates on a VI 60-s schedule were found to vary inversely with the density of the alternative schedule, with mean rates (across 5 rats) of 41% of the maximum when the alternative was VI 15-s, 70% when it was VI 30-s, 86% when it was VI 60-s, and 96% when it was VI 120-s. These findings illustrate the difficulty of comparing reinforcement rates across different experimental contexts, and suggest that reinforcement rate in itself may not be a useful index of reinforcer potency. With regard to the present research, the data on rate of timeout production probably should not be seen as offering conclusive evidence—pro or con—concerning the potency of timeout.

There were a number of procedural differences between Experiments 1 and 2 (e.g., duration and scheduling of sessions, specific stimuli used), but they did not appear to influence the reinforcing functions of timeout. In addition to demonstrating the reliability and generality of timeout reinforcement, the absence of differences may shed light on the

source of the effectiveness of timeout. In Experiment 1, sessions were preceded by a warmup period that included 30-min exposure to the shock-postponement schedule alone, without the opportunity to produce timeout. To the extent that the reinforcing properties of timeout derive from termination of conditioned aversive stimuli that accompany avoidance, one might expect regular, lengthy periods of uninterrupted exposure to the avoidance schedule to be required. Although avoidance-only periods may have contributed to the effectiveness of timeout, they were not necessary, as responding was well maintained in Experiment 2 even though the timeout schedule was operative throughout the procedure (including a 20-min warmup). Also relevant are results from the multiple VI EXT phases of the first experiment, in which avoidance-only periods (the EXT components) alternated with periods in which timeouts could be produced (the VI components). Response rates on the timeout lever were not consistently higher under these conditions than under conditions in which timeouts were available throughout the session proper (multiple VI VI). Thus, at least for purposes of response maintenance, it appears that the reinforcing function of timeout is related to *current* properties of the avoidance situation.

As Heline (1984) has noted, one way to expand the analysis of negative reinforcement beyond traditional studies of avoidance is to analyze the aversiveness of integrated behavioral situations involving stimuli, responses, and contingencies. The present research can be viewed in such terms. Because the subjects' responding was maintained by consequent transition from a situation in which an avoidance contingency was operative to one in which the contingency was suspended, the findings illustrate the aversiveness of the avoidance situation. But what was the critical difference between the avoidance and timeout situations? Experiment 2 showed that the stimulus changes accompanying the transition did not, by themselves, function as reinforcers. Another difference was the density or frequency of the shocks within the situations. During time-in, the rats' proficient avoidance led to mean shock rates that usually were below 0.3 shocks per min, and in several cases were below 0.05 (see Tables 1 and 2). Thus, transitions from avoidance to timeout were accompanied by

relatively small reductions in shock frequency. Although such reductions could conceivably maintain responding, they are much smaller than those occurring in studies that have specifically addressed the issue of reinforcement by shock-frequency reduction (e.g., de Villiers, 1974, reductions of about 0.6–3.6 shocks per min; Herrnstein & Heline, 1966, 3–9 shocks per min). On this basis, we suspect that shock-frequency reduction is not the primary source of the reinforcing properties of timeout, but of course a firm conclusion must await further data.

A third possible account of the effectiveness of timeout as a reinforcer emphasizes the aversive quality of the avoidance contingency itself—even though the behavior controlled by the contingency was highly successful in preventing shock. By producing timeout, the rats escaped a situation that required responding, entering an alternative situation without a response requirement. Note that this analysis is expressed in terms of the requirements of the avoidance *contingency* rather than the resulting avoidance *behavior*. Of course the analysis could be rephrased to emphasize the behavior and, given the dependence of the behavior on the contingency, the distinction may seem a minor one. Nevertheless, an advantage of the contingency analysis is that it points to an environmental variable that can be manipulated experimentally.

Although suspension of an avoidance contingency is a complex environmental event, it does have a clear locus in time and it can be scheduled in essentially the same way as simpler consequences such as food presentation. Thus, by allowing arrangement of negative reinforcement on a variety of schedules that parallel those used with positive reinforcement, the timeout procedure has the potential to facilitate direct comparisons of the two types of reinforcement.

A different way of comparing positive and negative reinforcement, based strictly on avoidance, has been developed in the context of quantitative formulations of the law of effect. Studies of responding on variable-cycle shock-deletion schedules have found that, with shock-frequency reduction as the measure of negative reinforcement, the relationship between response and reinforcement rates conformed to the matching law (de Villiers, 1972, 1974; Logue & de Villiers, 1978). Although

such an approach is of interest, we believe that the study of timeout offers several advantages. First, as noted in the introduction, the timeout procedure allows separate manipulation of establishing operations and reinforcement magnitude, whereas these are confounded in simple avoidance procedures. Second, use of timeout does not depend on an account of avoidance in terms of shock-frequency reduction—an account which is not universally accepted (cf. Dinsmoor, 1977). Third, use of timeout is not restricted to tests of the matching law, but may also be applied in areas beyond the scope of current versions of that law—for example, analysis of schedule-controlled response patterns. Of course, if difficulties continue to be encountered in maintaining responding under fixed-ratio schedules of timeout (see the Discussion section of Experiment 1), the use of this procedure to compare positive and negative reinforcement will be limited somewhat.

A final point concerns our reliance on the concept of negative reinforcement in interpreting the effects of timeout. Questions have been raised about the scientific and pedagogical value of this concept and, more generally, of the distinction between positive and negative reinforcement (Michael, 1975; Mixon, 1975). Our terminology is based on Skinner's (1953) operational classification that distinguished between strengthening behavior by presenting versus withdrawing stimuli. "Negative reinforcement" would seem to accurately describe the operations involved in our procedure: In the presence of a complex of discriminative stimuli and an ongoing avoidance contingency, responding initiated the withdrawal of both the stimuli and the contingency. The larger issue of whether such an operation is functionally equivalent to the presentation of an appetitive stimulus is an empirical one that the present procedure is well suited to address.

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