**CHAINED SCHEDULES OF AVOIDANCE:
REINFORCEMENT WITHIN AND BY
AVOIDANCE SITUATIONS**

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Four rats were exposed to chained schedules with variable-cycle avoidance in both links. Responding in the initial link cancelled shocks scheduled once per minute and, according to a conjoint fixed-ratio schedule, produced a terminal link where scheduled shock rates varied from 0 to 8 shocks per minute in different conditions of the experiment. Response rates in the terminal link increased as a function of the scheduled shock rate. Response rates in the initial link, on the other hand, decreased as a function of the shock rate actually received (rather than scheduled) in the terminal link. While consistent with other studies of aversive control, these results differ from those obtained in chained schedules of positive reinforcement in that increases in reinforcement within the terminal link of the chain did not systematically increase the reinforcing value of that link.

Key words: negative reinforcement, scheduled shock rate, chained schedules, variable-cycle avoidance, lever press, rats

In a two-link chained schedule of reinforcement, responses in the presence of an initial stimulus produce a second stimulus in the presence of which responses produce primary reinforcement. The stimulus signaling the terminal link is a discriminative stimulus for responding in its presence and it has been viewed as a conditioned reinforcer for responding in the initial link (Kelleher & Gollub, 1962).

Recent analyses of performance in chained schedules (e.g., Baum, 1973; Fantino, 1977) have questioned traditional views that the stimulus signaling the terminal link acquires independent reinforcing value. Instead, the reinforcement-like effects of the terminal link stimulus are attributed to its discriminative functions with respect to contingencies of primary reinforcement. From this standpoint, the function of the terminal link stimulus is to mark the transition from a situation of lower value to a situation of higher value—it is the situation transition that is reinforcing rather than the stimulus itself (Baum, 1973). According to recent views of chained schedule performance, then, initial link responding reflects

the reinforcing value of the terminal link which, in turn, derives from parameters of reinforcement within that link.

While chained schedules of positive reinforcement have been widely investigated (for a recent review, see Gollub, 1977), little is known about chained schedules of negative reinforcement. Using escape procedures, Dinsmoor and Clayton (1963) showed that responding in the presence of continuous shock was maintained by the production of a stimulus in the presence of which shock could be terminated by further responding. Hake (1968) subsequently found that responding in an initial link containing intermittent, unavoidable shocks was maintained by production of a terminal link where shocks could be avoided.

Since chained avoidance schedules have not been studied, one purpose of the present experiment was to examine performance in a schedule similar to that studied by Hake (1968), but with avoidance contingencies in both links. Responding in the initial link avoided shock and, according to a conjoint schedule, produced the terminal link. In different conditions of the experiment, the terminal link contained avoidance schedules with different shock rates. This procedure allowed assessment of two sources of reinforcement within the chained schedule: the reinforcing (or punishing) value of the terminal link, as indicated by facilitation (or suppression) of initial

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link responding, and reinforcement available within the terminal link, as indicated by rates of terminal link responding.

Performances in chained avoidance schedules may differ from performances in chained schedules of positive reinforcement. Response rates in the initial link of appetitive chained schedules are known to increase as a function of reinforcement provided in the terminal link (Kelleher & Gollub, 1962). In chained avoidance schedules, however, it is uncertain whether initial link response rates will increase or decrease as a function of reinforcement in the terminal link. In the present experiment, terminal link reinforcement was increased by scheduling higher shock rates so that responding produced greater reductions in shock frequency (Herrnstein, 1969). As a result, the value of the terminal link may be expected to increase as the scheduled shock rate increases. But scheduling higher shock rates usually leads to higher received shock rates, which may be expected to reduce the value of the terminal link (Hake, 1968). In the latter case, a procedure which increases reinforcement provided within the terminal link of a chained schedule would have the contrary effect of reducing the reinforcing value of that link. A second purpose of the present experiment, then, was to examine this potential discrepancy between chained schedules of avoidance and positive reinforcement.

METHOD

Subjects

Four male albino rats (Holtzman Co., Madison, Wisconsin) were experimentally naive and approximately 6 months old at the start of the experiment. Food and water were continuously available in the home cages.

Apparatus

A standard single-lever rodent chamber (Grason-Stadler, E3125C) was enclosed in a sound-attenuating chest. The lever was centered on the front wall, 9.5 cm above the grid floor, and required a minimum force of .4 *N* to be operated. General illumination was provided by a 3-W houselight mounted behind a translucent white screen on the right acrylic wall. A constant-current shock source (Grason-Stadler, E1064GS) delivered scrambled grid shock of 1.0 mA intensity and .3-sec duration.

Masking noise was provided by a ventilating fan and white noise. Programming and recording operations were performed by electromechanical equipment located in an adjacent room.

Procedure

Variable-cycle (VC) avoidance schedules were used in which lever-press responses cancelled shocks scheduled at irregular time intervals (deVilliers, 1972). Intershock intervals were drawn from the distribution of Fleshler and Hoffman (1962). The first response after a shock was due cancelled the next shock and additional responses within the intershock interval had no effect. On the basis of preliminary work, the avoidance schedules included two special features (cf. deVilliers, 1972). To exclude intershock intervals so brief as to make some of the shocks essentially unavoidable, the Fleshler-Hoffman series was modified so that the minimum intershock interval was 5 sec, except in the case of the shortest VC schedule (7.5 sec), where it was 2.5 sec. The schedules also included a shock-shock interval so that whenever a shock was delivered, additional shocks were delivered every 5 sec until a response occurred. This response restarted the VC schedule, and another response was required to cancel the next scheduled shock. The shock-shock interval was included to insure sustained responding, particularly during the initial stages of training. Once the avoidance response was well established, the shock-shock interval was rarely encountered (one exception is discussed below).

Except for the early stages of training, sessions were conducted on alternate days and lasted 2.5 hr. Each session began with the onset of white noise and ended with the white noise going off. Lever-press responses were accompanied by feedback consisting of .5-sec offset of white noise.

Lever-press responding was shaped in a single session, and then maintained for 4 to 8 hr on a fixed shock-delay schedule (Sidman, 1953a) with a 20-sec response-shock interval and a 5-sec shock-shock interval. Thereafter, VC avoidance was in effect, starting with a VC 15-sec schedule. After 10 hr of training, the schedule was changed in a series of steps to VC 60 sec, the baseline avoidance schedule for the remainder of the experiment. Training on VC 60-sec avoidance continued for 20

to 26 sessions, by which time the rats were avoiding at least 90% of the scheduled VC shocks and response rates showed no systematic changes over sessions.

The experiment proper began with the introduction of the chained schedule. During each session, six two-link chains were superimposed on the baseline avoidance schedule at irregular intervals. The initial link of the chain contained the VC 60-sec avoidance schedule and a conjoint fixed-ratio schedule requiring 10 responses (FR 10) to produce the terminal link. The terminal link of the chain lasted 5 min and was followed by a return to the baseline avoidance schedule. Manipulation of the mean intershock interval of the avoidance schedule in the terminal link formed the conditions of the experiment. The baseline and initial link avoidance schedules always were VC 60 sec.

The components of the chained schedule were signaled by the houselight. For all subjects, the houselight blinked on and off in .5-sec cycles during the initial link. For three rats (G5, G6, and G7), the chamber was darkened during the terminal link and illuminated during baseline avoidance. For Rat G3, the stimuli were reversed: illumination of the chamber signaled the terminal link, and darkness signaled the baseline avoidance schedule.

To obtain samples of behavior in the baseline condition comparable to those recorded for the chained schedule, baseline performance was recorded for a period equal to the duration of the terminal link, that is, for a 5-min period that preceded the onset of each chain in the session.

In the experimental conditions, the terminal link contained timeout from avoidance and VC schedules with mean intershock intervals of 60, 30, 15, and 7.5 sec, resulting in a series of scheduled shock rates (disregarding shocks scheduled by the shock-shock interval) of 0, 1, 2, 4, and 8 shocks per min. The number of sessions devoted to each condition is listed in Table 1, with the order given in parentheses. In the first condition for all rats, the baseline avoidance schedule (VC 60 sec) was placed in the terminal link to determine whether the stimuli signaling the chained schedule controlled different response rates. After training with VC 60 sec, the terminal link avoidance schedule was changed to VC 15 sec, followed by (in different orders for

Table 1

Experimental conditions and number of sessions in each. Conditions are specified by the VC avoidance schedule and corresponding scheduled shock rate in the terminal link. The order of conditions is given in parentheses. The number of sessions in the timeout condition is the final procedure in a series of timeout manipulations (see text).

Terminal link		No. of sessions (order)			
Avoidance schedule	Scheduled shocks/min	Rat G3	Rat G5	Rat G6	Rat G7
Timeout	0	16 (3)	18 (5)	19 (3)	—
VC 60 sec	1	28 (1)	21 (1)	12 (1)	19 (1)
VC 30 sec	2	16 (4)	20 (4)	15 (4)	25 (4)
VC 15 sec	4	14 (2)	22 (2)	20 (2)	31 (2)
VC 7.5 sec	8	18 (5)	20 (3)	17 (5)	15 (3)

pairs of rats) timeout from avoidance, VC 7.5 sec, and VC 30 sec.

Each terminal link schedule was continued until response rates in both links of the chained schedule were stable. The stability criterion required that, in the absence of a trend, mean response rates in the first two and last two sessions of four consecutive sessions were within 10% of the mean for the four sessions.

The timeout condition posed a special problem in that responding during timeout was remarkably persistent. Timeout originally involved eliminating all shocks during the 5-min terminal link. But when responding showed no signs of weakening after 15 to 35 sessions, additional procedures were instituted. First, to increase contact with the absence of shock the duration of the timeout period was increased from 5 min, the standard duration, to 60 min. Within a few sessions, responding was absent for the entire timeout period and the timeout duration then was progressively reduced from 60 min back to the original 5 min. Under this procedure, however, responding recovered with the 5-min timeout duration and continued to occur in an irregular fashion for 12 to 22 subsequent sessions. Thus, in a final, radical change in procedure, the white noise was turned off during the 5-min timeout period, a procedure which also removed the feedback for responding. Under these conditions, responding during timeout dropped rapidly to near-zero levels and did not recover. Since stable performances were not obtained in the series of timeout manipulations, data are presented only from the final timeout procedure. During this series of manipulations, Rat G7

contracted a respiratory infection and was dropped from the experiment.

RESULTS

The typical findings of the experiment are illustrated in Figure 1 by segments of cumulative records taken from the final session in each condition for Rat G6. The first part of each record, starting when the response pen was reset, constitutes the 5-min period that preceded each chain when data were recorded from the baseline VC 60-sec avoidance schedule. With the onset of the initial link of the

chain, the response pen was held in the down position until the FR 10 requirement was completed and the terminal link began. The pen then returned to the up position. The end of the terminal link and reinstatement of the baseline schedule is shown by the dot above each record. Shocks are indicated by upward deflections of the pen during the initial link and by downward deflections elsewhere.

Figure 1 shows that when timeout was scheduled in the terminal link and responding was virtually absent for the duration of the terminal link, response rates in the initial link increased above baseline levels. When VC 60-sec avoidance was scheduled in the terminal link as well as in the baseline and initial link, the rate of responding was relatively constant throughout the baseline and both links of the chained schedule. Then, as the mean inter-shock interval of the terminal link avoidance schedule was reduced from 60 sec to 30 sec, 15 sec, and finally 7.5 sec, response rates in the terminal link progressively increased while response rates in the initial link decreased. At the shortest intershock intervals (VC 15 sec and VC 7.5 sec), initial link responding was characterized by long pauses between responses, occasionally resulting in receipt of shocks.

The cumulative records in Figure 1 also show that responding was closely controlled by the chained schedule stimuli. Presentation of the initial link stimulus was accompanied by high rates of responding when timeout was scheduled in the terminal link and by low rates of responding when VC 15 sec or VC 7.5 sec was scheduled. The change from initial to terminal link response rates also was fairly abrupt, although, as is evident in Figure 1, at the shortest mean intershock intervals shock rates typically were highest in the initial portions of the terminal link. Finally, when the terminal link ended, responding quickly returned to the baseline rate.

The results are summarized more comprehensively in Figure 2 where response rates on the baseline avoidance schedule and in both links of the chained schedule are plotted as a function of the shock rate of the VC schedule in the terminal link. Response rates in the terminal link are indicated by squares connected by solid lines, response rates in the initial link by circles connected by dashed

Fig. 1. Segments of cumulative records from the final session in each condition for Rat G6. The response pen was reset at the start of the 5-min period preceding each chain when data were recorded from the baseline avoidance schedule (VC 60 sec). The pen was held in the down position during the initial link and returned to the up position at the onset of the terminal link. The end of the terminal link is indicated by the dot immediately above each record. Shocks are indicated by upward deflections during the initial link and by downward deflections elsewhere.

lines, and baseline response rates by unconnected triangles. Data points are mean response rates over the four criterion sessions with the range indicated by vertical lines.

Response rates on the baseline avoidance schedule fluctuated somewhat across conditions, but did not vary systematically with the shock rate scheduled in the terminal link. In one case, the variability in baseline response rate was correlated with the order of conditions; the baseline rate of Rat G3 decreased throughout the course of the experiment.

Figure 2 shows that when the baseline avoid-

ance schedule, 1 shock per min (VC 60 sec), was contained in the terminal link, response rates in the baseline, initial link, and terminal link were nearly equal. But with scheduled shock rates other than 1 per min, response rates in the initial and terminal links diverged in opposite directions from the baseline rate.

With regard to performances in the terminal link, response rates increased as a direct function of terminal link shock rates. The only irregularity was in the case of Rat G3 where the response rate did not increase when the

Fig. 2. Response rates in the baseline (triangles), initial link (circles), and terminal link (squares) as a function of the shock rate scheduled by the mean intershock interval of VC avoidance schedule in the terminal link. The scheduled shock rate in the baseline and initial link was always one shock per min (VC 60 sec). Data points are means of the last four sessions with the range indicated by vertical lines.

shock rate was increased from 1 to 2 shocks per min (VC 60 to VC 30 sec). As a result of the special procedures used for timeout, terminal link rates were close to zero when no shocks were scheduled. At 2 shocks per min, terminal link rates exceeded baseline rates in two rats (G5 and G7) and, at 4 (VC 15 sec) and at 8 (VC 7.5 sec) shocks per min, terminal link rates were well above baseline rates in all four rats.

The major concern of the present experiment was with the influence of the terminal link on response rates in the initial link. There is a clear relationship at the extremes of the functions shown in Figure 2. Initial link rates increased above baseline levels when responding produced timeout (0 shocks per min) and decreased below baseline levels when responding produced the avoidance schedule with the highest potential shock rate, i.e., 8 shocks per min. At intermediate shock rates, however, the relationship between response rates in the initial link and shock rates scheduled in the terminal link is more complex.

As noted earlier, when 1 shock per min was scheduled in the terminal link, baseline and initial link response rates did not differ. But baseline and initial link rates also did not differ when 2 shocks per min were scheduled in the terminal link. At 4 scheduled shocks per min, baseline and initial link rates of Rats G5 and G7 still did not differ, while the initial link rates of Rats G3 and G6 dropped below their baseline rates. Thus, initial link response rates did not always decrease with increases in scheduled shock rate in the terminal link, and the point at which initial link rates decreased varied for different rats.

Since initial link responding was not systematically controlled by shock rates scheduled in the terminal link, a further analysis was conducted to determine the extent of

control by shocks received in the terminal link. Table 2 gives the actual terminal link shock rates. Virtually all shocks were delivered by the VC schedule; shocks delivered by the shock-shock timer were very infrequent (less than 2% of the total number of shocks received). Table 2 shows that received shock rates did not increase in parallel to scheduled shock rates. The low rates of received shocks when 1 shock per min was scheduled did not increase substantially when 2 shocks per min were scheduled. For these small increases in received shocks in the terminal link, initial link response rates did not decrease substantially in any rat (see Figure 2, circles). At 4 scheduled shocks per min, received shock rates again increased by only relatively small amounts in Rats G5 and G7, the two rats whose initial link response rates did not decrease. By comparison, the increases in received shock rates at 4 scheduled shocks per min were larger in Rats G3 and G6, and the initial link response rates of these rats did decrease. Finally, at 8 scheduled shocks per min, received shock rates of all four rats showed large increases, and initial link responding was markedly reduced in all four. Thus, reductions of response rates in the initial link were associated with increases in received shock rates in the terminal link.

Control of initial link responding by received shocks in the terminal link is made evident in Figure 3 where suppression of initial link response rates relative to baseline rates [in the ratio $A/(A + B)$, where A is initial link rate and B is baseline rate] is plotted as a function of received shock rate in the terminal link. The bracketed points at zero shocks show facilitation of initial link responding when the terminal link consisted of timeout. The cluster of points around a ratio of .5 show that initial link responding was not suppressed when received shock rates in the terminal link were relatively low. The remaining points show suppression of initial link responding at higher received shock rates. Even though the rats differed in the scheduled shock rate at which pronounced increases were observed in the rate of received shocks (see Table 2), Figure 3 shows that initial link rates were suppressed only in conditions where the received shock rates for individual rats were substantially higher than in other conditions. In addition, two rats (G3 and G6) showed greater degrees of suppression with further in-

Table 2

Received shock rates in the terminal link. Tabled values are means of the final four sessions in each condition with ranges given in parentheses.

Scheduled shocks/min	Received shocks/min			
	Rat G3	Rat G5	Rat G6	Rat G7
1	.08 (.13)	.01 (.05)	.02 (.03)	.02 (.06)
2	.27 (.27)	.01 (.03)	.12 (.05)	.03 (.06)
4	1.15 (.37)	.07 (.10)	.57 (.67)	.17 (.20)
8	2.78 (.24)	1.35 (1.56)	1.62 (.33)	1.39 (.66)

Fig. 3. Suppression of initial link responding as a function of received shock rate in the terminal link. The suppression ratio is the initial link response rate divided by the sum of the initial link and baseline response rates in each condition. The bracketed points at zero received shocks were obtained when the scheduled shock rate also was zero, that is, when timeout from avoidance was scheduled in the terminal link.

creases in received shock rate, although suppression at the highest shock rate in Rat G3 was attenuated by a low baseline response rate in this the final condition of the experiment.

Received shock rates in the terminal link as shown in Table 2 may be compared to received shock rates on the baseline avoidance schedule. Throughout the experiment, received shock rates during the baseline were below .1 shocks per min, with the exception of Rat G3 who received .16 shocks per min in the baseline during the final condition. Thus, the above findings may be cast in terms of the difference between received shock rates during the baseline and terminal link: suppression of initial link responding was observed only when received shock rates in the terminal link exceeded those in the baseline by a substantial margin.

Finally, received shock rates in the initial link of the schedule varied with the terminal link avoidance schedule. In conditions where initial link responding was not suppressed (when the terminal link contained timeout, VC 60 sec, or VC 30 sec), initial link shock rates were lowest (range = .0 to .23 shocks per min). The shock rates increased somewhat in the VC 15-sec condition (range = .03 to .32

shocks per min), and were highest in the VC 7.5-sec condition (range = .14 to .42 shocks per min). Thus, suppression of initial link responding by the densest shock schedule (VC 7.5 sec) in the terminal link may have been constrained by the rate of shocks received as responding decreased. Nearly all shocks received in the initial link were delivered by the VC schedule, with the exception of Rats G3 and G6 in the VC 7.5-sec condition where 61% and 56% of the shocks, respectively, were delivered by the shock-shock timer.

DISCUSSION

In the chained VC avoidance schedules of the present experiment, responding in the initial link had the dual consequences of avoiding shock and producing a terminal link containing another avoidance schedule. As the mean intershock interval of the terminal link schedule was reduced, response rates in that link increased. But while terminal link responding was controlled by the rate of scheduled shocks, responding in the initial link was controlled by the rate of *received* shocks in the terminal link. Response rates in the initial link were facilitated when all shocks were omitted in the terminal link and suppressed when increasing scheduled shock rates resulted in increased rates of received shock in the terminal link.

These relationships between response and shock rates in chained avoidance schedules are consistent with other studies of aversive control. First, the inverse relationship between response rates and the mean intershock interval of the avoidance schedule in the terminal link is very similar to the relationship found in simple VC avoidance schedules (deVilliers, 1974), and parallels the effects of varying the response-shock interval in fixed shock-delay schedules (e.g., Sidman, 1953b). Second, facilitation of initial link responding by timeout in the terminal link shows that timeout from avoidance is an effective reinforcer (cf. Baron & Trenholme, 1971; Verhave, 1962). Finally, suppression of initial link responding by received shocks in the terminal link appears similar to the type of control reported by Hake (1968), who found that initial link responding which produced a change from unavoidable to avoidable shock was maintained as long as the rate of received shocks in the terminal link

was less than the rate of unavoidable shocks in the initial link.

Suppression of initial link responding by shocks received in the terminal link may be attributed in a straightforward manner to increases in shock frequency (Rachlin & Herrnstein, 1969). Interpretation of findings with regard to terminal link responding is not as simple, however, and depends on whether scheduled shock rates are specified in terms of the intershock interval of the VC avoidance schedules or in terms of the shock-shock interval contained in the schedules.

We chose to specify scheduled shock rates exclusively in terms of the intershock interval of the VC avoidance schedule for the following reasons. First, the results indicated that as the VC interval was reduced, both response rates and received shock rates increased. But the shock rate scheduled by the shock-shock interval was fixed at 12 per min in all conditions of the experiment. Thus, if reinforcement is identified as reductions in shock frequency (cf. Herrnstein, 1969) and the scheduled shock rate is specified by the shock-shock interval, one is led to the contradictory conclusion that terminal link responding *increased* as the reinforcement for responding *decreased*.

Other reasons for basing scheduled rates on the VC interval are that shocks scheduled by the shock-shock interval were rarely encountered (less than 2% of the total) and that the findings were quite similar to those reported by deVilliers (1974), whose VC schedules did not include a shock-shock interval. Finally, specification of scheduled shock rates in terms of the VC interval allows straightforward interpretation of performances in the terminal link of the chained schedule. The finding that terminal link responding increased as the mean intershock interval decreased can be attributed to increased reinforcement stemming from greater reductions in shock frequency (deVilliers, 1974; Herrnstein, 1969).

Although performances in chained avoidance schedules fall in line with previous studies and current interpretations of aversive control, they differ in an important way from performances in chained schedules of positive reinforcement. As noted above, response rates in both links of appetitive chained schedules increase as a function of reinforcement in the terminal link (Kelleher & Gollub, 1962). Thus,

Baum (1973) suggested that reinforcement *within* a situation (such as the terminal link of a chained schedule) is the basis for the reinforcing value of that situation. In the chained avoidance schedules studied here, however, initial link response rates sometimes were unchanged and sometimes decreased as reinforcement and response rates in the terminal link increased. Thus, reinforcement of avoidance responding within the terminal link was not, in any clear way, the basis for the reinforcing or punishing value of the terminal link.

The present results indicated that the value of the terminal link decreased as a function of the number of shocks actually received, independent of reinforcement of avoidance responding within the terminal link (see also, Hake, 1968). There is a counterpart to this finding in the case of punishment. Schuster and Rachlin (1968) showed that the reinforcing value of terminal links containing shock punishment decreased as a function of rate of punishment, and that the decrease in value was independent of whether shock punishment was response-contingent or response-independent. In conjunction with Schuster and Rachlin's findings, then, the present findings support the conclusion that the value of situations containing shock depends on the rate at which shocks are delivered, regardless of whether the shocks are independent of responding, positively related to responding by way of punishment contingencies, or negatively related to responding by way of avoidance contingencies.

The discrepancy between chained schedules of avoidance and positive reinforcement may have resulted from the way in which terminal link reinforcement was manipulated in the present experiment. Reinforcement and scheduled shock rate covaried in the terminal link because both are altered by the mean intershock interval (Hineline, 1977). Thus, although reinforcement within the terminal link increased as the mean intershock interval was reduced, the denser shock schedules sometimes led to higher rates of received shock, and the shocks actually received controlled the reinforcing value of the terminal link.

It is worth noting that the confounding of reinforcement and scheduled shock rate is not an inevitable consequence of using free-operant avoidance procedures (see Hineline, 1977).

For example, Neffinger and Gibbon (1975) manipulated reinforcement independently of scheduled shock rate by varying the probability of a shock given a response, while holding constant the probability of shock in the absence of responding. If these procedures were used to schedule identical shock rates in both links of a chained avoidance schedule, the value of a terminal link providing more reinforcement might well be greater than the value of one providing less reinforcement. Such a finding would, of course, parallel those ordinarily obtained when terminal link reinforcement is varied in chained schedules of positive reinforcement.

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