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RESPONDING UNDER SCHEDULES COMBINING RESPONSE-DEPENDENT AND RESPONSE-INDEPENDENT SHOCK DELIVERY[1]

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Lever pressing of three squirrel monkeys with experience under continuous avoidance schedules was maintained by response-produced shock under a 5-minute variable-interval schedule. Responding decreased when half of the scheduled shocks were delivered independently of lever pressing and decreased further when all shocks were independent of lever pressing. Responding was lowest when all shocks were eliminated. When the proportion of response-dependent shocks increased, responding increased. This relation occurred even though the frequency and temporal distribution of shock delivery remained the same. Responding of two monkeys increased in a graded fashion as the frequency of shock was increased by arranging variable-time 5-minute, 2-minute, and 1-minute schedules jointly with the variable-interval 5-minute schedule. Thus, increasing the proportion of response-independent shocks decreased responding when the overall frequency of shocks stayed the same, but increased responding when the overall frequency of shock delivery increased.

Key words: VI schedules, VT schedules, response-dependent shock, response-independent shock, squirrel monkeys

The effects of events on behavior depend not only on their frequency and temporal distribution (Catania and Reynolds, 1968; Ferster and Skinner, 1957), but also on the dependency between those events and the behavior that precedes them (Herrnstein, 1966; Lattal, 1974, 1973; Zeiler, 1968). For example, in one experiment (Lattal, 1974) the proportion of response-dependent and response-independent food deliveries was varied with the total number and temporal distribution of food presentations held constant. In that experiment, the rate of key pecking maintained under variable-interval (VI) schedules decreased as the percentage of response-independent food deliveries varied between 0% and 100%. Response rates also decreased when both the proportion of response-independent food deliveries and, consequently, the overall frequency of food deliveries increased (Rachlin and Baum, 1972). In that study, key pecking was maintained under VI schedules of food presentation while, jointly, food delivery was arranged independent of a response under several variable-time (VT) schedules. Since increasing the frequency of response-dependent food delivery under similar schedules generally increases responding (Catania and Reynolds, 1968) this latter study further points out that response dependency, apart from frequency and temporal distribution of food delivery, also controls response rates.

While these studies indicate that the presence of response-independent events is sufficient to reduce responding maintained by the same event scheduled response-dependently, several studies suggest the importance of other variables in determining the magnitude and direction of rate changes. Response rate, reinforcement frequency, and the duration of a stimulus preceding response-independent food presentation influence the magnitude of rate change (Smith, 1974). For example, low response rates may be increased by response-independent food presentation (Herrnstein and Morse, 1957; Neuringer, 1970) or by response-independent presentation of a stimulus previously paired with food presentation (Herrnstein and Morse, 1957; Morse, 1955; Morse and Skinner, 1957).

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Responding can be maintained at constant rates when each response delays the scheduled presentation of electric shock (shock-postponement schedule; *cf.* Sidman, 1966). Several studies (Jones, 1969; Sidman, Herrnstein, and Conrad, 1957) have reported that response-independent shock delivery, arranged jointly with shock-postponement schedules, results in an overall increase of lever pressing of rats and monkeys. Other studies have shown an increase in responding during a stimulus preceding response-independent shock delivery (Kelleher, Riddle, and Cook, 1963; Waller and Waller, 1963). This effect may also occur on schedules of response-dependent food presentation in monkeys with a history of exposure to a shock-postponement schedule (Herrnstein and Sidman, 1958). However, other studies investigating lever pressing of rats found decreases under some conditions when response-independent shocks were arranged with shock-postponement schedules (Shimoff, Snapper, and Schoenfeld, 1972; Sidman, 1966).

Lever pressing can be maintained by schedules of response-dependent shock presentation in monkeys with prior exposure to schedules of shock postponement (McKearney, 1974*a*; 1972; 1970; *cf.* Morse and Kelleher, 1970). Response rates and patterns under schedules of shock presentation are comparable to those under schedules of food presentation. McKearney (1974*a*) demonstrated that response-shock dependency is important in maintaining responding under fixed-interval schedules of shock presentation. In that study, response rates maintained under fixed-interval (response-dependent) schedules of shock presentation were higher than response rates under comparable fixed-time (response-independent) schedules of shock presentation.

The present study investigated the effects of combinations of response-independent and response-dependent electric shocks on behavior maintained by response-produced shocks. Its purpose was to compare these effects with effects obtained in studies that used shock postponement and food presentation schedules to maintain responding. Responding was first maintained under a VI schedule of shock presentation, and then the proportion of shocks arranged response-dependently was changed but the overall frequency of shock was held constant. Subsequently, responding was extinguished, and the proportion of response-independent shocks again varied. The present study also investigated the effect of changes in the overall frequency of shocks by delivering shocks under several VT schedules jointly with shocks delivered under a VI schedule.

METHOD

Subjects

Three male squirrel monkeys (*Saimiri sciureus*) had all been exposed to various schedules of shock postponement and shock presentation before the present experiment.

Apparatus

Experiments were conducted with individual monkeys seated in a restraining chair (Hake and Azrin, 1963; Kelleher and Morse, 1964) housed in a sound-attenuating chamber. Electric shocks (650 V ac, 200 msec) were delivered through series resistance to metal electrodes that rested on a shaved portion of the tail. Shock intensity was 5.2 mA for S-528 and 10 mA for S-512 and S-531. A response lever (BRS/LVE No. 121-05), requiring 0.196 N downward force for activation, was mounted on a clear Plexiglas panel facing the monkey. A 7-W white light mounted behind this panel illuminated the chamber throughout each session.

Procedure

An arithmetic variable-interval (VI) schedule operated continuously during each session, but stopped when response-dependent shocks were scheduled. This schedule provided an average of one shock each 5 min (range: 3 to 600 sec). Delivery of 20 response-dependent shocks terminated each session under all conditions except during extinction sessions, which were terminated after 100 min.

Constant shock frequency. Under the first set of conditions, delivery of all shocks depended on a response according to the VI schedule (0% response-independent condition). Subsequently, either half (50%) or all (100%) of the shocks were instead delivered independently of responding. This was followed by removal of all shocks (EXT). The initial conditions were then reinstated in a different order. A single tape puller programmed all shock deliveries. Each response-independent shock occurred immediately

when scheduled, without respect to lever pressing.

Under the 50% response-independent condition, shocks were arranged either as response independent or as response dependent, according to a pseudo-random distribution. No more than three response-dependent or response-independent shocks could occur consecutively. Any scheduled response-dependent shock had to occur before further shocks were delivered. Conditions were changed when responding was stable, but some conditions were investigated for a greater number of sessions in order to assess stability of responding over a longer period of exposure.

Variable shock frequency. The VI 5-min response-dependent shock schedule was reinstated. Variable-time schedules (VT 5-min; VT 2-min; VT 1-min) were then arranged jointly. Thus, the proportion of response-independent shocks, as well as the overall frequency of shocks, varied. The two schedules operated independently of each other; shocks were programmed from separate tape pullers. Response-independent shocks occurred immediately when programmed, whereas the tape puller stopped until a response occurred when response-dependent shocks were scheduled.

The exact sequences and the number of sessions of exposure to experimental conditions for each monkey are presented in Table 1. Sessions were conducted five days a week.

Table 1

Sequences of Experimental Conditions

Per Cent Response-Independent Shock	*Number of Sessions*		
	S-512	*S-528*	*S-531*
CONSTANT SHOCK FREQUENCY			
0%	11	30	19
50%	13	16	38
100%	20	27	20
(EXT)	7	20	5
100%	20	15	37
50%	24	13	38
0%	23	32	17
VARIABLE SHOCK FREQUENCY			
VI 5-min schedule	(- -) 23	(- -) 40	(- -) 37
jointly arranged	(VT 2) 16	(VT 5) 21	(VT 5) 21
with VT schedule	(VT 1) 22	(- -) 20	(VT 2) 17
in parentheses	(VT 2) 16	(VT 2) 20	(- -) 11
		(VT 1) 22	(VT 2) 11
			(VT 1) 11
			(- -) 11
			(VT 5) 11

RESULTS

Steady rates of responding were maintained by the variable-interval schedule of shock presentation, as has been reported (Barrett, 1975; McKearney, 1974*b*). With the overall frequency of shocks held constant, response rates (responses per second) of all monkeys decreased as the percentage of response-independent shocks increased (Figure 1, filled circles). Response rates were lower when shocks were removed (EXT) than when all shocks were delivered response-independently (100% VT). Although response rates under the VT condition may have declined even further with extended exposure, there was a clear difference between the rate decreases under the VT and EXT conditions. During extinction, rates decreased rapidly over a few sessions, whereas under the VT schedule, rates decreased gradually over many sessions.

Response rates of S-512 and S-528 increased when the percentage of response-dependent shocks increased during redetermination (open circles). Response rates under each condition during redetermination were lower than under initial exposure. Response rates of S-531 under the 0% condition (VI) were lower than under the 50% condition during redetermination. This may reflect an effect of the order of exposure to redetermination conditions (50%, 100%, 0%).

Although response-independent shock could not occur until scheduled response-dependent shocks were delivered, response rates under the 50% and 100% conditions were high enough to prevent delays in the delivery of response-independent shock. Thus, the obtained shock frequency closely approximated the scheduled shock frequency.

Changes in response rate under the joint VI VT schedules are shown as a function of the frequency of response-independent shocks in Figure 2. Under this set of conditions, the overall frequency of shocks varied, as well as the frequency of response-independent shocks. For two of the three monkeys, response rates increased slightly with increases in the frequency of shock under the VT schedule. For the third monkey, response rate was constant over the lower frequencies of response-independent shock, and decreased slightly at the highest frequency.

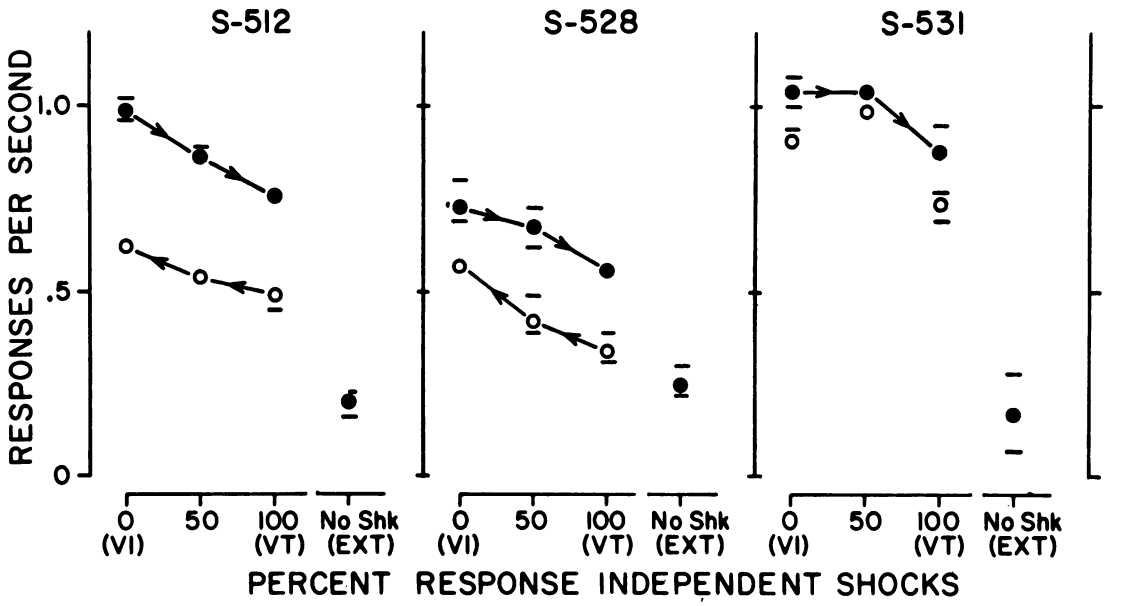

Fig. 1. Response rate as a function of per cent response-independent shocks. Initial determinations are represented by filled circles, redeterminations by open circles. Data points are means of last three sessions under each condition; ranges are indicated by horizontal lines about each point, except where variability is within the area covered by the circles. Arrows indicate the order of exposure to successive conditions. Open circles are not connected on the function for S-531 because of the different order of exposure to conditions during redetermination (50%, 100%, 0%).

DISCUSSION

The present data are consistent with previous studies (McKearney, 1974*a*; Morse and Kelleher, 1970) in showing that response dependency is an important factor in the maintenance of responding under schedules of shock presentation. These studies and the present results indicate that responding under schedules of shock presentation is most directly controlled by the dependency between response and shock, and not simply the presence of shock or a history of responding under shock-postponement schedules. In addition, the present investigation extends these findings by showing that combinations of response-

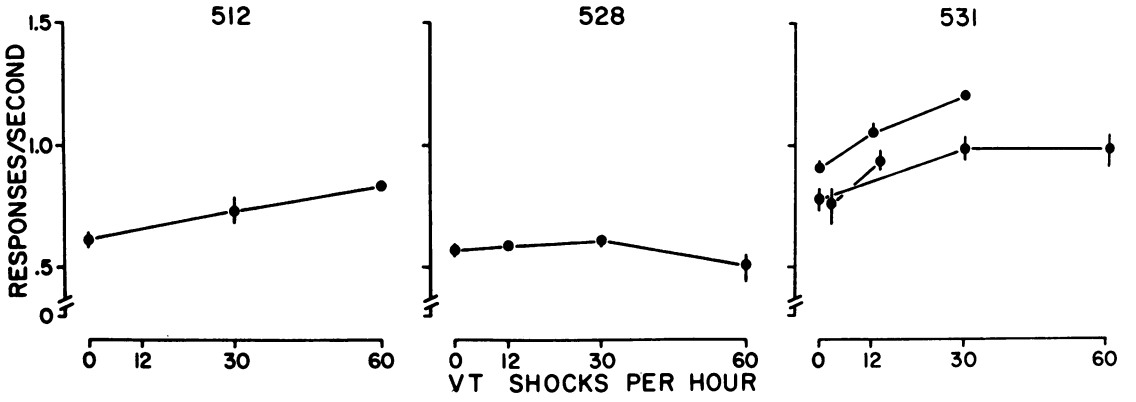

Fig. 1. Response rate as a function of per cent response-independent shocks delivered under the VT 5-min, VT 2-min, and VT 1-min schedules. A VI 5-min schedule jointly arranged response-dependent shocks. Data are means of the last three sessions under each condition; ranges are indicated by vertical lines through the data points, except where variability is within the area covered by the circles. Several conditions were replicated with S-531 on separate occasions. Note that the Y-axis is discontinuous with the origin.

dependent and response-independent shock can, under different conditions, control response rates either higher or lower than those maintained by a schedule in which all shocks are delivered response dependently.

Changes in either the frequency of shock or the proportion of response-independent shock changed the rate of responding maintained under the schedule of shock presentation. When the frequency and pattern of shock delivery was held constant, there was a direct relation between response dependency and response rate. A direct relation between response rate and response dependency has been reported with responding maintained under VI schedules of food presentation (Lattal, 1974). Although response rates of S-531 were lower under the VI schedule than when half of the shocks were delivered response independently (Figure 1, redetermination), the data were consistent with the effects of changes in response dependency obtained with the other monkeys. That is, response rates increased with increases in the proportion of response-dependent events (VT to VI) and decreased with decreases in the proportion of response-dependent events (50% dependent to VT). When both the frequency and the proportion of response-independent shocks were increased, response rates either increased or remained unchanged. Baum and Rachlin (1972) reported that response rates decreased when overall frequency of food and the proportion of response-independent food delivery increased, but in other studies (Herrnstein and Conrad, 1957; Kelleher, Riddle, and Cook, 1963; Waller and Waller, 1963), delivery of response-independent shocks increased responding of monkeys with prior shock-postponement training.

The hysteresis evident between the first and second determinations of changes in the proportion of response-independent shock (Figure 1) may have been related to the response rate existing before changes in the response dependency. Response rates were lower during redetermination (following exposure to extinction) than during initial exposure to the same conditions. The absolute response rate maintained by each condition appeared to depend on whether responding was maintained initially at a high rate under the VI schedule or at a low rate under extinction. Additional research may be warranted to clarify this point, but these results are consistent with previous reports (Herrnstein and Morse, 1959; Neuringer, 1970; Smith, 1974) that have shown the importance of ongoing response rate in determining the effect of additional response-independent food delivery on responding maintained by response-produced food delivery.

The difference in the effects of response-independent events between conditions in the present study appeared to be related to whether or not overall shock frequency was increased. However, shock frequencies in each condition were not comparable. Future investigations of both food-maintained and shock-maintained responding should study the effects of response-independent events on responding that is initially maintained by different parameters of response-dependent schedules. In addition, it may be noted that a response-independent shock was specified in terms of the program of events, not by the monkeys' behavior. Since the delay between a lever press and independent shock was not restricted, some of those shocks may actually have been contiguous with a response. It would be informative for future studies to measure the actual delay between responses and independent events. It is not clear, however, how scheduled independent shocks in the present experiment, even if occasionally contiguous with a response, would result in decreases in rates in one condition and increases in rates in another.

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