RELATIVE FREQUENCY OF REINFORCEMENT AND RATE OF PUNISHED BEHAVIOR¹

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After training on a multiple variable-interval variable-interval schedule of reinforcement, each response in one component of the schedule was followed by a brief electric shock. When the rate of punished responses stabilized, the frequency of reinforcement in the other component was first decreased and then increased from the baseline frequency. The effects of these manipulations were consistent with reports of interactions in multiple schedules involving only unpunished behavior, *i.e.*, the rate of punished responses increased with a higher relative frequency of reinforcement in the punishment component and decreased with a lower relative frequency of reinforcement in that component. The relevance of such findings to a further generality of behavioral contrast effects is discussed.

Frequency of reinforcement may be stated in either absolute or relative terms. In the latter case, multiple schedule components often provide the basis for comparisons between behavioral effects of different reinforcement frequencies. Changes in the absolute frequency of reinforcement in one component of the multiple schedule, while leaving absolute reinforcement frequency in the other component(s) unchanged, also alters the relative frequency of reinforcement in these unchanged components. Beginning with Reynolds (1961a, b, c; 1963) a number of investigators have assessed the behavioral effects of such changes (*e.g.*, Bloomfield, 1967; Catania and Gill, 1964; Nevin and Shettleworth, 1966). Generally, increasing or decreasing the relative frequency of reinforcement in one component of a multiple schedule respectively increases or decreases the response rates in that component (but see Reynolds, 1963, for limiting cases). Some generality of such effects has been established by the observation in multiple avoidance schedules that changes in the response-shock interval in one component were associated with changes in the rate of

avoidance behavior in a second component associated with a constant response-shock interval (Wertheim, 1965). The rate of unpunished responses in one component of a multiple schedule is also sensitive to manipulations in the intensity of a punishing stimulus delivered after each response in a second component. Such increments in unpunished responding do not necessarily result from a change in the relative frequency of reinforcement, but they have been interpreted as being similar to the behavioral contrast effects brought about by manipulations in the relative frequency of reinforcement (Brethower and Reynolds, 1962).

Attempts to control the rate of punished behavior by the manipulation of variables in other components of multiple schedules of reinforcement have met with varied success. Edwards and Dart (1967) unsuccessfully attempted to increase behavior completely suppressed by punishment in one component of a multiple fixed-ratio fixed-ratio (*mult* FR FR) schedule by increasing the intensity of electric shock punishment delivered for the first response in the other component. Rachlin (1966, Exp. 2) found that the introduction of punishment in one component of a multiple variable-interval variable-interval (*mult* VI VI) schedule had a reliable facilitative effect upon the rate of punished behavior in a second component. Rachlin's findings suggest a contrast effect upon punished behavior similar to that reported by Brethower and Reynolds (1962). The present experiment extends

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Rachlin's results by examining the effects of different frequencies of reinforcement of unpunished behavior upon the rate of punished behavior maintained under a constant absolute reinforcement frequency in a second component of a *mult* VI VI schedule.

METHOD

Subjects

Two adult Silver King pigeons, each with a history of approximately 40 sessions of exposure to a *mult* VI VI schedule with a VI 15-sec punishment schedule in one component, were maintained at 80% ($\pm 1.5\%$) of free-feeding weight throughout the experiment.

Apparatus

A sound-attenuating operant conditioning chamber of the type described by Ferster and Skinner (1957) was used. The dimensions of the work area were 11.5 by 12 by 15.5 in. (30 by 32 by 39.5 cm). A single translucent pigeon response key was located 8.5 in. (22 cm) from the floor and 3.5 in. (9 cm) to the right of the midline of the work panel. It was transilluminated by a 7-w red or green light bulb at all times except during reinforcement and timeout periods as indicated below. A 28-v dc relay provided auditory feedback each time the response key was operated. Reinforcement was a 3.5-sec access to Purina mixed pigeon grain from a Gerbrands food magazine. Supporting relay circuitry and recording equipment were located in an adjacent room.

Nichrome wire electrodes were implanted bilaterally beneath the pubis bones of each subject (Azrin, 1959). Sixty Hz ac electric shock was delivered to these electrodes through a Powerstat variable autotransformer and 10 K ohms resistance in series with the subject. Shock intensities were measured by attaching a milliammeter directly to the shock lead-in wires in the operant chamber. Daily resistance measures of each subject were also taken and this resistance was maintained approximately constant at 2000 ohms throughout the experiment.

Procedure

Since both subjects had experience on a similar multiple schedule, they were placed directly on a *mult* VI 2-min VI 2-min schedule. Green and red keylights served as the dis-

criminative stimuli for either component. The two components of the multiple schedule alternated every 3 min and were separated by a 2-sec period of total darkness in the chamber (timeout). Reinforcements primed but not collected during either component were automatically cancelled at the end of that component. Each daily session consisted of 14 exposures to each component of the schedule. After stable multiple schedule performance developed (modified from the criterion of Schoenfeld, Cumming, and Hearst, 1956) a 60-msec electric shock was delivered after each response in the VI 2-min component associated with the red keylight (red component). The intensity of the punishing stimulus was gradually increased over several sessions until the response rates in the red component were reduced to at least 50% of the unpunished rate in this component. Shock intensities of 4.6 and 3.8 mA resulted in stable mean response rate reductions of 56 and 97% for P12 and P14 respectively. After this stable response rate reduction was attained in the punishment component, several manipulations in the schedule (frequency) of reinforcement in the no-punishment component were made. These manipulations are summarized in Table 1. After each reinstatement of the VI 2-min schedule in the no-punishment (green) component the response rates in both components were stabilized before the next manipulation.

RESULTS

All scheduled reinforcements under each of the multiple schedule components described in Table 1 were collected, even though the response rates in the two components differed markedly. The mean number of reinforcements collected in either component during the experiment is indicated in Table 1. Introduction of the punishing stimulus in the red component resulted in suppression of the response rates in accord with previously published accounts (Azrin, 1960; Brethower and Reynolds, 1962). These response rate reductions are illustrated in Fig. 1. The punishment did not result in consistent response-rate increments in the unpunished VI behavior of either subject (*cf.* Brethower and Reynolds, 1962). This is illustrated in the second and third panels of Fig. 2. The rates of responding in red and green are shown during the first

Table 1

Sequence of reinforcement schedules in effect in the no-punishment (green) component, with VI 2-min (+ FR 1 punishment) always scheduled in the punishment (red) component.

Schedule of Reinforcement in No-Punishment Component	P 12			P 14		
	Number of Sessions	$\bar{X}$ Reinforcements per Minute		Number of Sessions	$\bar{X}$ Reinforcements per Minute	
		Green	Red		Green	Red
VI 2-min	15	0.51	0.50	14	0.50	0.49
Extinction	12	0.00	0.50	12	0.00	0.45
VI 2-min	17	0.49	0.51	17	0.49	0.49
VI 30-sec	12	1.93	0.49	12	2.00	0.49
VI 2-min	14	0.51	0.49	17	0.50	0.50

six punishment sessions and the last six punishment sessions before the manipulations of reinforcement frequency.

The sample cumulative records in Fig. 1 illustrate the general effects of each manipulation of the reinforcement schedule in the no-punishment component upon the rate of response in the punishment component. Figures 2 and 3 provide a more detailed analysis of

the response rates during these manipulations. Figure 2 shows the absolute response rates in both red and green during the different conditions of the experiment. In Fig. 3, each daily response rate in the punishment (red) component has been transformed to a percentage deviation from the mean punishment response rate of the six sessions immediately preceding the indicated manipulation (see figure legend for details). Only the first 12 sessions of each condition in the experiment are depicted in Fig. 3. A reduction in the absolute frequency of reinforcement in the no-punishment component to zero (VI 2-min to extinction and hence an increase in the relative frequency of reinforcement in the punishment component) facilitated the rate of punished responding above the previously established baseline response rates in this component. Although higher than the punishment rate during the immediately preceding condition, the punishment response rate did not reach the level of unpunished responding observed in this component during the original baseline condition. A subsequent increase in the absolute frequency of reinforcement in the no-punishment component (extinction to VI 2-min) generally resulted in decrements in the punishment response rates, relative to the punishment rates observed during the *mult* VI 2-min EXT sessions. Although the rates of response in the punishment component decreased initially upon a return to *mult* VI 2-min VI 2-min, the punishment rates tended to stabilize after several sessions at approximately the level observed in this component during *mult* VI 2-min EXT.

An increase in the absolute frequency of reinforcement in the no-punishment component (VI 2-min to VI 30-sec and hence a decrease in the relative frequency of reinforcement in

Fig. 1. Sample cumulative records of the performance of P 12 during each manipulation of reinforcement frequency in the no-punishment (green) component. The schedule of reinforcement in effect in the no-punishment component is indicated above each cumulative record. "N" or "P" indicate, respectively, the absence or presence of FR 1 punishment in the red component. The response pen reset after each component.

Fig. 2. Response rates in both components during each condition of the experiment. "N" and "P" indicate, respectively, the absence or presence of FR 1 punishment in the red component. The schedule of reinforcement in the green component is also indicated. The second and third blocks of sessions (VI 2,P) are the first and last six sessions of the initial exposure to punishment.

the punishment component) resulted in decrements in the response rates in the punishment component below the preceding stable punishment response rate. These rates were consistently below the preceding baseline level and, for P 12, often below the original punishment response rates. Decreasing the absolute frequency of reinforcement in the no-punishment component (VI 30-sec to VI 2-min) resulted in increases in the punishment rates of response.

DISCUSSION

These results lend support to a contention that variables removed from the stimulus conditions in which punishment occurs may exert control over the punishment rate of response. Although the absolute frequency of reinforcement in the punishment component remained unchanged throughout the experiment, the relative frequency of reinforcement in that component changed considerably as a result of the manipulations in reinforcement frequency in the no-punishment component. The effects of such changes are consistent with Reynolds' (1961 *et seq.*) results and extend the generality of those observations to situations involving punished behavior. Tullis and Wal-

ters (1968) and Holz (1968) suggested that the absolute frequency of reinforcement is not an important consideration in determining the degree of response suppression produced by punishment. The present findings suggest, however, that the relative frequency of reinforcement must be considered in the control of the rate of punished behavior.

The initial introduction of punishment in one component of the multiple schedule did not result in the marked facilitation of the no-punishment response rates as found by Brethower and Reynolds (1962). There are, however, several other investigations that do not report such consistent facilitation of unpunished behavior (Azrin, 1956; Dinsmoor, 1952; Rachlin, 1966). One possible explanation in the present case is that both subjects had a previous history of punishment (40 sessions of VI 15-sec punishment in one component) and such a history of punishment may diminish the occurrence of such effects, much as a history of extinction reduces the degree of behavioral contrast in positive reinforcement schedules (Terrace, 1966, Exp. I). The discrepancy between the present findings, along with those of Rachlin and Brethower and Reynolds (1962) only suggest the need for further investigation of the parameters of

Fig. 3. Sessional percentage deviation of the punishment rates of response from the mean of the immediately preceding six-day period as a function of changes in the relative frequency of reinforcement of punished behavior. The first schedule in the legend was in effect during Session 0, the second during subsequent sessions.

punishment-produced contrast effects within multiple schedules.

In both subjects there was a tendency for the rate of punished behavior to increase across successive returns to the *mult* VI 2-min VI 2-min schedule. That the punishment response rate did not return to the original level of suppression upon a return to *mult* VI 2-min VI 2-min after the block of sessions with extinction in the no-punishment component was not unexpected. Several studies indicate that punishment response rates recover to some extent with long-term exposure to punishment, as was the case in the present investigation (Azrin and Holz, 1966). The facilitated response rates in the punishment component during the increased relative frequency of reinforcement in that component (VI 2-min to EXT in green) resulted in more deliveries of

the punishing stimulus and hence greater opportunity for adaptation to the effects of the electric shock punisher. The decrease in rate associated with a decrease in the relative frequency of reinforcement in the punishment component (EXT to VI 2-min in green) indicates that, despite progressive adaptation to the punishing stimulus, the punishment rate of response can still be suppressed to a lower level as a function of reinforcement related variables. This response-rate suppression observed despite increasing adaptation suggests also that the response rate increments obtained in the punishment component during *mult* VI 2-min EXT were not simply a function of adaptation to the electric shock punisher. This observation is further supported by the fact that the punished behavior was suppressed to a lower level upon introduction of a VI 30-sec schedule of reinforcement in the no-punishment component.

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