SOME EFFECTS OF RESPONSE INDEPENDENT REINFORCERS IN MULTIPLE SCHEDULES¹

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In Exp. I, rats' lever presses were conditioned on multiple variable-interval variable-interval schedules. Changing one of the multiple schedule components to variable time reduced responding in that component. Further reductions in responding occurred in both components when the schedule was changed to multiple variable-time variable-time. After reinstating the multiple variable-interval variable-time schedule, lower response rates were maintained in the variable-time component during a series of stimulus reversals. In Exp. II, replacement of extinction components of multiple variable-interval extinction or multiple extinction extinction with variable-time schedules for single sessions (probe) resulted in response rate increments in those components. In the former schedule these increases were concomitant with response decreases during the variable-interval components. Response increases in the variable-time probes were related to conditioning history and, as a result, to response probability at the time of the probe.

Positive reinforcers may be delivered dependent upon a specified response or independently of an animal's behavior. Zeiler (1968) designated schedules employing response independent reinforcers as time schedules (*e.g.*, fixed time or variable time) to differentiate them from analogous interval schedules employing response dependent reinforcers. If behavior is conditioned on interval schedules, the usual finding is that response rates decrease when time schedules are substituted. For example, following conditioning on multiple fixed-interval fixed-interval (Appel and Hiss, 1962) or multiple variable-interval variable-interval (Weisman, 1970) schedules, pigeons were shifted to multiple fixed-interval fixed-time or multiple variable-interval variable-time schedules. Responding during the time components decreased across several sessions, while the rates of response in the interval components showed no system-

atic change. In these experiments, there was "a substantial rate of response in the free reinforcement situation [time schedule component] . . . at the end of training in every case" (Appel and Hiss, 1962, p. 38).

Under other conditions, however, response independent reinforcers may increase baseline rates of response. Herrnstein and Morse (1957) occasionally presented a 2-min change in key color transillumination to pigeons whose responses were being reinforced with response dependent food according to a differential-reinforcement-of-low-rate schedule (DRL 5-min). Rates of responding increased during the stimulus change when the change terminated with a 5-sec response independent presentation of grain (hence, a fixed time 2-min schedule). These response rate increases reached a stable level in three to five days and were "in excess of the control value by a factor of about 3" (Herrnstein and Morse, 1957, p. 464). Other experiments have shown that delivery of response independent reinforcers during regular extinction (defined here as an absence of any reinforcer presentation, either dependent or independent of responding) often results in response rate increases. Spradlin, Girardeau, and Hom (1966); Campbell, Phillips, Fixsen, and Crumbaugh (1968); and Spradlin, Fixsen, and Girardeau (1969) trained rats or retarded children on fixed-or variable-ratio schedules and then extinguished the re-

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sponse. Single response independent reinforcers were then presented during regular extinction after predetermined time intervals in which responding did not occur. These reinforcers generally caused increases in response rate immediately after presentation, but the magnitude of the increases dissipated with successive presentations of the response independent reinforcers. Rescorla and Skucy (1969, Exp. 3 and Exp. 4) also found response rate increases when a variable-time schedule was introduced following several sessions of extinction. Response rates were lower in the second of the two sessions that the schedule was in effect (Exp. 4, Group Food-Bar).

The present experiments examined some of the conditions under which response independent reinforcers, delivered according to variable-time schedules, maintain and reinstate responding when arranged in components of multiple schedules. The development of response rate differences during variable-interval (VI) and variable-time (VT) schedules was studied using rats as subjects. Particular attention was given to interactions between VI and VT components and to responding in the presence of response independent reinforcers during successive stimulus reversals. The effects of VT probes following regular extinction in one or both components were studied in the second experiment.

EXPERIMENT I. RESPONDING DURING VARIABLE-INTERVAL AND VARIABLE-TIME COMPONENTS FOLLOWING VARIABLE-INTERVAL CONDITIONING

METHOD

Subjects

Four experimentally naive male albino rats were maintained at 80% ($\pm 3\%$) of free-feeding weight. Each was approximately 120 days old at the beginning of the experiment.

Apparatus

A Lehigh Valley Electronics model 1417 rat chamber was equipped with a Davis model 104 pellet dispenser that delivered standard 45-mg Noyes pellets as reinforcers. The operandum was a Lehigh Valley model 1352 rate lever that was operated by a minimum force of approximately 0.14 N. White noise

was used to mask extraneous sounds during the experiment. Digital logic control and recording equipment were located in an adjacent room.

Procedure

After the rats were trained to bar press, each was placed on a multiple variable-interval 1-min variable-interval 1-min (*mult VI 1-min VI 1-min*) schedule in which components alternated every 5 min. Bright and dim levels of houselight illumination, generated by the 30-v ac and 10-v ac outputs of a Lehigh Valley model 1429 ac transformer panel, were the discriminative stimuli for the two components. Each session began with the bright component and ended after six presentations of each (1 hr). Reinforcers primed but not delivered during any component were cancelled at the end of that component. Sessions were conducted five days a week.

When stable performance developed in both components (a difference of not more than 5% between the means of the first and last three sessions of six successive sessions) the VI 1-min schedule associated with the dim stimulus light was changed to variable-time 1-min (VT 1-min). It was identical to the previous VI 1-min schedule except for the elimination of the response-reinforcer dependency. *Mult VI 1-min VT 1-min* was in effect for 35 sessions, when the response ratio (VI responses / (VI responses + VT responses)) did not vary by more than 0.10 over five successive sessions. Next, the response-reinforcer dependency was also removed from the bright component, converting the schedule to *mult VT 1-min VT 1-min*. It was in effect for 10 to 25 sessions. Variable interval 1-min was then reinstated in the bright component for an additional 10 sessions. Successive transitions for VI to VT in the two components were then examined in a series of stimulus reversals. In the first of these, the houselight was dim during the VI component and bright during the VT component for 35 to 37 sessions. The stimuli were then reversed to reinstate the original condition (VI bright, VT dim) for 10 to 20 sessions. Third and fourth reversals were studied in three of the animals.

RESULTS

Stable *mult VI VI* performance was obtained 19, 20, 21, and 16 sessions after bar-

Fig. 1. Response rates during *mult* VI VT and *mult* VT VT following *mult* VI VI conditioning.

press shaping with Rats 12, 23, 24, and 26 respectively. The first panel of Fig. 1 shows that the response rates in the two components were approximately equal at this point. The development of response rate differences between VI and VT components is shown in the second panel of Fig. 1. Response rates during the VT component gradually decreased across the 35 *mult* VI VT sessions. Response rate patterns during VI were more variable. With Rats 23 and 26, some increases in VI responding above the previous baseline rate developed toward the last sessions of this condition, but this effect was not entirely consistent nor was it observed with Rats 12 and 24. A tetrachoric correlation coefficient was computed to determine further the relation between the directions of response rate changes in the two components during *mult* VI VT. This correlation coefficient has been used previously for a similar purpose (Wertheim, 1965). It was calculated by combining data from all four animals to obtain a sufficient number of observations and was 0.707, which for this number of observations is significantly

different from zero ($p < 0.001$). Thus, the direction of VI and VT response rate changes in any session relative to the response rates in the immediately preceding session were highly positively correlated.

The effects of changing from *mult* VI VT to *mult* VT VT are illustrated in the third panel of Fig. 1. With each animal, there is a reduction in responding during both VT components, relative to response rates observed during the preceding condition. A return to *mult* VI VT increased responding in both components. Such reductions and increases in responding in both components of a multiple schedule following a manipulation in only one component are examples of negative and positive induction (Reynolds, 1961b).

The results of the stimulus reversals are presented in Fig. 2. The response rates of each animal (lower portion of each animal's data) were converted into a response ratio (top portion) by the formula: VI response rate / (VI response rate + VT response rate). Ratios greater than 0.50 indicate that higher response rates were obtained in VI and ratios

Fig. 2. Response rates and response ratios during the stimulus reversals. The conditions in effect in each panel from left to right are given at the top of the figure. The response ratios are given in the top portion and responses per minute are given in the lower portion of each animal's section of the figure. Circles represent VI rates and triangles represent VT rates in the lower portions.

less than 0.50 indicate the reverse, *i.e.*, higher rates in VT. For all subjects, the first sessions of the reversal resulted in greater responding during VT than during VI. After several sessions, however, the response rates became relatively higher during VI. The response ratios were not, within the arbitrary limits of the stability criterion, as high as those observed before the reversal. A return to the original stimulus conditions generally resulted in higher rates in VT for a few sessions followed by a return of higher rates in VI. These find-

ings were replicated during the third and fourth reversals.

EXPERIMENT II. RESPONDING DURING VARIABLE-TIME PROBES FOLLOWING REGULAR EXTINCTION

Subjects

Three experimentally naive male albino rats, as described in Exp. I, were used.

Fig. 4. Number of responses during *mult* VT VT probes following *mult* EXT EXT. The number of responses during probe sessions are shown in the middle pair of bars in each panel. The first and last pairs of bars in each panel are the mean number of responses during the four sessions preceding and following the probe sessions. The dashed lines separate successive pre-probe, probe, and post-probe sequences for each animal.

DISCUSSION

The results of Exp. I, like those of Appel and Hiss (1962) and Weisman (1970), show that consistent response rate differences develop between interval and time components of multiple schedules. Such differences appear gradually over many sessions and the direction of the response rate changes in the components are highly positively correlated. Similar data have previously been interpreted as a discrimination of response independent reinforcers. The present data present a clearer picture of the discriminative properties of the response-reinforcer relationship by showing that such discriminative performance can be reestablished during successive reversals of the exteroceptive stimuli associated with the two components.

Conditioning history was important in several instances in determining response rates controlled by VT schedules. Neuringer (1970) showed that substantially greater responding is maintained during time schedules if conditioning with response dependent reinforcers precedes introduction of the response independent reinforcers. In each of the present animals, such a history of response dependent reinforcer delivery was first established. The VI conditioning history, in combination with the interactions between VI and VT components, resulted in the maintenance of generally higher, more consistent VT response rates than have been reported in VT schedules studied separately (Neuringer, 1970; Rescorla and Skucy, 1969; and Zeiler, 1968). Again, higher VT response rates were also maintained in the VT component associated with VI for longer periods of time upon introduction of *mult* VT VT.

The interactions that occurred in Exp. I when the bright component schedule was changed from VI to VT and back to VI suggest that VT components control relatively higher rates of response if they occur in sequence with other components in which the probability of a response is relatively high. Reynolds (1961*b*) found that response rates during a regular extinction component were temporarily increased by reinforcing responding in a second component. Such rates were consistently decreased by extinguishing responding in the second component. The response rate increases in VT upon return to

mult VI VT after *mult* VT VT are more persistent than those reported by Reynolds, but otherwise such induction effects in VT resemble those observed by him in regular extinction components.

Extinguishing responding in one component while continuing to reinforce responding in a second component results in response rate increases in the second component (Reynolds, 1961*a, b*). This behavioral contrast effect has at different times been attributed to the reduction in reinforcement frequency (Reynolds, 1961*a*) or to a reduction in response rates (Terrace, 1968) during extinction. Experiment I data are not clear on this point. Consistent behavioral contrast did not occur in the VI component when response rates were reduced in the other component by changing to a VT schedule that maintained the same reinforcer frequency as during *mult* VI VI (*cf.* also Appel and Hiss, 1962; Weisman, 1970). There are, however, some VI response rate increases with Rats 23 and 26 after several *mult* VI VT sessions. It should also be noted that the response rates during VT were only gradually reduced and did not reach as low a level as is usually observed after this number of sessions of regular extinction.

Variable-time probes following regular extinction in one or both components of multiple schedules result in response increases similar to those reported by Rescorla and Skucy (1969) in single schedules. These increases also resemble the effects of single response independent reinforcers delivered during regular extinction after periods of no responding (Campbell, *et al.*, 1968; Spradlin, *et al.*, 1966, 1969). The relatively persistent, frequent VT responding in the present experiment seems to be related to the animal's conditioning history and, consequently, to response probability at the time of the probe session. Like the rats in Exp. I, those in Exp. II had extensive conditioning with response dependent reinforcers prior to EXT. This history, in conjunction with the interactions that occur in such multiple schedules (Reynolds, 1961*b*, 1964) accounts for the maintained responding in the EXT components of *mult* VI EXT. Even during the last sessions of *mult* VI EXT, rates of up to 10 responses per minute were common. As a result, delivery of response independent reinforcers

would be likely to occur contiguous with responses, thereby increasing future response probability. Such a sequence of events would then continue to occur as long as VT was in effect with the resulting maintenance of VT responding.

Differences in the VT response increases during *mult* VI VT and those during *mult* VT VT following *mult* EXT EXT are also related to response probability at the time of the probe session. In *mult* EXT EXT responding was further reduced in both components and the absolute response increases during VT probes were predictably lower than those obtained in the preceding *mult* VI VT probe conditions. During these probes following *mult* EXT EXT, greater increases consistently occurred in the component associated with VI for more sessions and therefore with generally higher EXT response rates. These response increases in both components were generally higher after fewer sessions of EXT, when EXT response rates were also higher.

Increased VT responding occurred concomitantly with decreased VI responding during the VT probe sessions following *mult* VI EXT. It is not possible, however, independently to attribute this negative contrast to increased VT responding or to increases in relative reinforcer frequency in this component during such probes (*cf.* Reynolds, 1961a; Terrace, 1968).

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