Whether or not the same results can be obtained with the human eyeblink CR, on which the VT model was based, remains a problem for further research. As presently formulated, however, the VT model does not appear to be able to account for such effects.

REFERENCES

FREY, P. W. Within- and between-session CS intensity performance effects in rabbit eyelid conditioning. Psychonomic Science, 1969, 17, 1-2.

GORMEZANO, I. Classical conditioning. In J. B. Sidowski (Ed.), *Experimental methods and instrumentation in psychology.* New York: McGraw-Hill, 1966. Pp. 385-420.

GRICE, G. R. Stimulus intensity and response evocation. Psychological Review, 1968, 75, 359-373.

GRICE, G. R., & HUNTER, J. J. Stimulus intensity effects depend upon the type of experimental design. Psychological Review, 1964, 71, 247-256.

GRICE, G. R., HUNTER, J. J., KOHFELD, D. L., & MASTERS, L. Order of presentation, CS intensity, and response latency. Journal of Experimental Psychology, 1966, 72, 510-513.

GRICE, G. R., MASTERS, L., & KOHFELD, D. L. Classical conditioning without discrimination training: A test of the generalization theory of CS intensity effects. Journal of Experimental Psychology, 1966, 72, 510-513.

HULL, C. L. Stimulus intensity dynamism (V) and stimulus generalization. Psychological Review, 1949, 56, 67-76.

ISON, J. R., & LEONARD, D. W. Effects of auditory stimuli on the amplitude of the nictitating membrane reflex of the rabbit *(Oryctolagus cuniculus).* Journal of Comparative & Physiological Psychology, 1971, in press.

McGILL, W. J. Loudness and reaction time. Acta Psychologica, 1961, 19, 193-199.

McGILL, W. J. Stochastic latency mechanisms. In R. D. Luce, R. R. Bush, and E. Galanter (Eds.), *Handbook of mathematical psychology.* Vol. 1. New York: Wiley, 1963.

Independence of postreinforcement pause length and running rate on fixed-interval pacing reinforcement schedules

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Two rats were exposed to a series of fixed-interval pacing schedules of reinforcement requiring a specific interresponse time for reinforcement after a fixed period of time had elapsed since the last reinforcement. Independent manipulations of the length of the fixed interval and the interresponse time required for reinforcement showed that the postreinforcement pause and the running rate on fixed interval schedules could be independently altered. The length of the fixed interval determined the length of the postreinforcement pause, and the reinforced interresponse time determined the response rate once responding began in an interval.

In fixed-interval (FI) schedules of reinforcement, the first response to occur following the elapse of a fixed time interval from the last reinforcement is reinforced. Following exposure to a short (e.g., 30-60 sec) FI schedule, the pattern of response within each interval tends to become break-run. That is, there is a postreinforcement pause (break) followed by a rapid transition to a

steady response rate (run) that is maintained until the next reinforcement (Schneider, 1969; Sherman, 1959).

A number of recent studies have been concerned with the interactions between variables controlling pause length and running rate. In particular, these studies have manipulated the response-reinforcement contingency in various ways, while maintaining the basic FI schedule. Farmer & Schoenfeld (1964), for example, added a contingency to the FI schedule in which, for a response to be reinforced, it must not only occur

following the end of the fixed-time interval but also not less than a minimum time since the last response. This had the effect of lowering the running rate without greatly affecting the length of the postreinforcement pause. More recently, other investigators (Kileen, 1969; Neuringer & Schneider, 1968; Shull, 1970) have tampered in various ways with the response-reinforcement contingency on FI schedules with similar results. That is, changes in running rate produced by restrictions on the response-reinforcement relation do not affect the duration of the postreinforcement pause. None of these studies, however, has attempted to manipulate the duration of the postreinforcement pause and to observe the effects of such manipulation on the running rate.

Studies that have manipulated the length of the interval in an FI schedule provide another means of examining the interactions between postreinforcement pause and running rate. In these cases, there is a clear interaction between the two measures of FI performance. For example, Sherman (1959) has shown that the postreinforcement pause is a direct function of interval duration, and Catania & Reynolds (1968) have shown that the running rate in normal FI schedules is also a function of the FI duration. The present study was an attempt to determine if independence between running rate and postreinforcement pause could be obtained by restricting the interresponse times (IRTs) that were followed by reinforcement. The procedure used is similar to that of Farmer & Schoenfeld (1964), with the exception that an upper, as well as a lower, limit is placed on the IRTs that qualify for reinforcement. These schedules are designated as FI pacing schedules of reinforcement. Both FI duration and reinforced IRT bands were separately manipulated, allowing the effects of a restricted response-reinforcement relation upon postreinforcement pause and the effects of FI duration upon running rate to be observed.

METHOD

Two experimentally naive male albino rats served as Ss and were maintained at 85% of their estimated normal body weights, as determined from a growth curve for animals of their strain. Supplementary food was given following each session. In conducting the research described in this report, the investigator adhered to the "Guide for Laboratory Animal Facilities and Care," as promulgated by the Committee on the Guide for Laboratory Animal Facilities and Care of the Institute of Laboratory Animal

Resources, National Academy of Sciences—National Research Council.

A Foringer rat box served as the experimental chamber. The operandum was an inverted microswitch arm which the animals pushed up with their noses (Crossman, 1963). Reinforcements were .045-g Noyes pellets. Electromechanical programming and recording apparatus was used.

IRTs were collected in 11 bins, with the boundaries of the bins approximately equal logarithmic increments apart. Thus, each bin was longer than its predecessor, with the shortest bin being from 0.0 to 0.39 sec and the 10th bin being from 30.32 to 45.32 sec. The 11th bin contained all IRTs longer than 45.32 sec.

Following initial magazine training and one session in which each response was reinforced, Ss were run on FI pacing schedules where the FI duration was either 30 or 60 sec and either IRTs in the fourth (1.37 to 2.44 sec) or the sixth (4.49 to 7.56 sec) bin were reinforced, depending on the experimental condition. Sessions were terminated after either 60 (FI 60-sec conditions) or 120 (FI 30-sec conditions) reinforcers. A given combination of FI and reinforced IRT remained in effect for at least 20 daily experimental sessions and until the performance appeared stable by visual inspection of cumulative records and IRT distributions. Following stabilization, either the length of the FI or the reinforced IRT was changed. Transitions from one experimental condition to the next were made over the course of several sessions to prevent severe disruption of the animals' behavior. Rat 9 was exposed to all four possible combinations of FI duration and reinforced IRT and Rat 10, to three of the four.

RESULTS

Figure 1 shows the effects of different FI durations and reinforced IRT bins on the median IRT, once responding began in an interval. In this figure, white bars represent IRTs when the FI duration was 30 sec and the crosshatched bars are from the FI 60-sec conditions. Comparison of the two pairs of bars for Rat 9, for example, shows that the median IRT depended only on the reinforced IRT bin and not on the length of the FI. The data for Rat 10 are similar but less complete.

Figure 2 shows the effects of the different FI durations and reinforced IRTs on the mean postreinforcement pause. In this figure, white bars represent data from conditions where only IRTs in Bin 4 were reinforced, and the crosshatched bars are from the
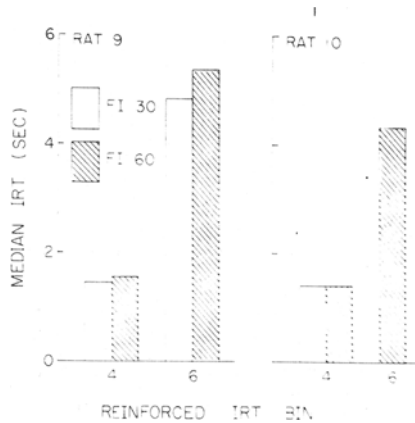

Fig. 1. Median interresponse times, once responding began in an interval for all experimental conditions. White and crosshatched bars are from conditions with different FI durations.

conditions where IRTs in Bin 6 were reinforced. In all cases, the mean postreinforcement pauses for the FI 30-sec conditions are shorter than those for FI 60-sec conditions. In no case is there any systematic difference in pause duration that is related to the reinforced IRT.

DISCUSSION

The invariance in the postreinforcement pause when median IRT (or running rate) was altered further extends the generalization that the exact response-reinforcement relation plays little part in determination of the postreinforcement pause on an FI schedule. The major variable that influences pause duration is length of the FI.

The close relation between the reinforced IRT and the median IRT is not surprising in light of the data on differential reinforcement of low rate schedules (e.g., Anger, 1956) and
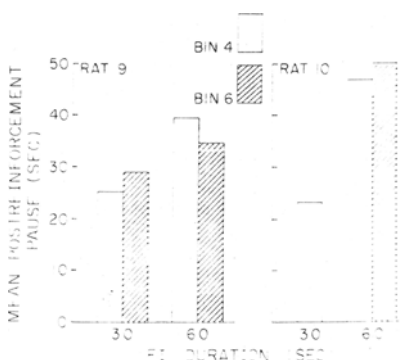

Fig. 2. Mean postreinforcement pause durations from all experimental conditions. White and crosshatched bars are from conditions with different reinforced interresponse times.

variable-interval pacing schedules (Ferster & Skinner, 1957; Revusky, 1963). These data show that the explicit reinforcement of IRTs exerts strong control over response rate. However, the existence of this relationship does not necessarily implicate the reinforced IRT as the principal determinant of running rate on nonpaced FI schedules. The addition of the pacing contingency constitutes a restriction of the animals' behavior that does not exist in the normal FI schedule. The fact that behavior conforms to the pacing contingency may indicate that reinforcement of IRTs is a sufficient condition for control of running rate and not that it is a necessary one. Other factors, such as amount of reinforcement or overall rate of reinforcement, are free to act in the nonpaced schedule and may play important roles in the determination of running rate. The present results do indicate, however, that there is no necessary interaction between postreinforcement pause and running rate on FI schedules, as each can be separately manipulated by the appropriate operations.

REFERENCES

ANGER, D. The dependence of interresponse times upon the relative reinforcement of different interresponse times. Journal of Experimental Psychology, 1956, 52, 145-161.
CATANIA, A. C., & REYNOLDS, G. S. A quantitative analysis of the responding maintained by interval schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1968, 11, 327-383.
CROSSMAN, E. K. A nose operandum for rats. Journal of the Experimental Analysis of Behavior, 1963, 6, 524.
FARMER, J., & SCHOENFELD, W. N. Effects of a DRL contingency added to a fixed-interval reinforcement schedule. Journal of the Experimental Analysis of Behavior, 1964, 7, 391-399.
FERSTER, C. B., & SKINNER, B. F. Schedules of reinforcement. New York: Appleton-Century-Crofts, 1957.
KILEEN, P. Reinforcement frequency and contingency as factors in fixed-ratio behavior. Journal of the Experimental Analysis of Behavior, 1969, 12, 391-395.
NEURINGER, A. J., & SCHNEIDER, B. A. Separating the effects of interreinforcement time and number of interreinforcement responses. Journal of the Experimental Analysis of Behavior, 1968, 11, 661-667.
REVUSKY, S. H. Effects of hunger and VI value on VI pacing. Journal of the Experimental Analysis of Behavior, 1963, 6, 163-169.
SCHNEIDER, B. A. A two-state analysis of fixed-interval responding in the pigeon. Journal of the Experimental Analysis of Behavior, 1969, 12, 677-687.
SHERMAN, J. G. The temporal distribution of responses on fixed-interval schedules. Unpublished doctoral dissertation, Columbia University, 1959.
SHULL, R. L. The response-reinforcement dependency in fixed-interval schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1970, 14, 55-60.