THE RELATION OF AMOUNT OF REINFORCEMENT TO PERFORMANCE UNDER A FIXED-INTERVAL SCHEDULE

W. C. STEBBINS, P. B. MEAD, and J. M. MARTIN

HAMILTON COLLEGE

Manipulation of the concentration of a soluble nutrient has been employed as a method of varying amount of reinforcement. This method is advantageous for two reasons: first, it controls stimulation prior to ingestion, and, second, it reduces variation in required ingestive activity. Guttman (1953, 1954) has shown that time to condition the bar-press response under regular reinforcement, resistance to extinction after regular reinforcement, and rate under fixed- and variable-interval schedules are each directly related to the percentage sucrose concentration, from 0 to 32% used as reinforcement for food-deprived white rats. Guttman (1954) has further demonstrated the semilogarithmic nature of the rate-concentration curve under a 1-minute, variable-interval schedule: the function passes through a maximum between the 20 and the 32% concentrations of sucrose.

Results by Stebbins (1959) and Verhave (1955) support Guttman's findings. Stebbins found a very sharp decline in rate on a 1-minute, variable-interval schedule when a 50% sucrose concentration was used. In an experiment by Conrad and Sidman (1956), rhesus monkeys were reinforced with varied sucrose solutions on a variable-interval schedule of reinforcement. Lever-pressing rates were highest between 15% and 32% sucrose concentration, and declined to a low value at 60% sucrose concentration.

The purpose of the present study was to determine the effect of varying amounts of primary reinforcement in units of percentage sucrose concentration on the behavior of a rat working under a 2-minute, fixed-interval schedule of reinforcement.

METHOD

Subjects

Subjects for this study were two experimentally naive male albino rats of the Wistar strain, both approximately 120 days old at the beginning of experimentation. During the weeks of experimentation and for several days preceding, the subjects were restricted to 1 hour of dry Purina pellets immediately after running time. The animals lived in separate cages, and had free access to water in their home cages.

Apparatus

The experimental chamber was a modified Grason-Stadler Rat Box adapted to present liquid reinforcement. The volume of liquid, presented by the dipper, was 0.02 milliliter. A Gerbrands punched-tape interval programmer made one reinforcement available at the end of every 2-minute interval, the 2 minutes being timed from the last occurrence of reinforcement. Four concentrations of sucrose solution were used: 5.0, 12.7, 32.0, and 50% by weight. Tap water was used as a solvent, and all solutions were prepared from commercial granulated sugar. The data were recorded on counters and on a cumulative recorder.

Procedure

On the first experimental day the animals were conditioned to bar press and were given 150 regular reinforcements, with the 12.7% solution as reinforcing agent. Following conditioning, animals were run for 2 hours daily; experimental days were consecutive.

Initially, the subjects were run under the 2-minute, fixed-interval schedule with the 12.7% solution as reinforcement. After 10 days, the behavior was stable (i.e., consistent daily response rates and similar daily response distributions throughout the 2-minute interval).

The same schedule was continued throughout the experiment, with the four sucrose solutions as reinforcement in the following mixed order: 32.0, 5.0, 50.0, and 12.7%, respectively. Each animal was run for two sessions (a total of 4 hours) under each concentration. The 12.7% solution was presented at both the beginning and conclusion of the experiment, in order to determine whether changes in behavior were due to manipulation of the concentration value or simply to extended exposure to the fixed-interval schedule.

RESULTS AND DISCUSSION

Figure 1 is a plot of the response rates (representing the final 2 hours under each concentration) for each animal against log percentage sucrose concentration. The points labelled A represent the final performance for both animals under the 12.7% concentration; the points labelled B represent the rate during the final session of fixed-interval training

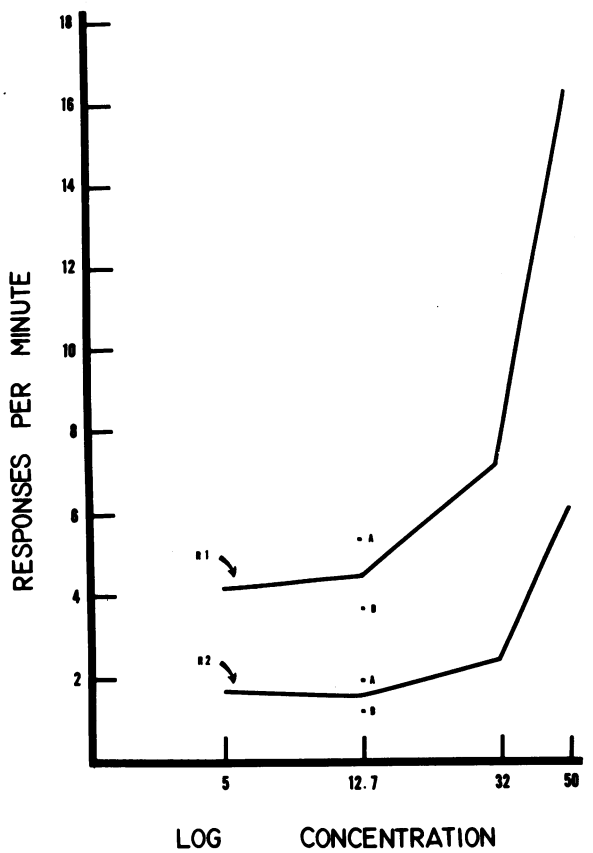

Figure 1. Response rates as a function of percentage of sucrose concentration. The concentration values are plotted on a logarithmic scale.

prior to the introduction of the other concentrations. The function has been drawn midway between these two points. For both functions, only a slight difference in rate is indicated between the 5.0% and the 12.7% concentrations. The response rates for both *S*s increase from the 12.7% to the 32.0% concentration. This finding is similar to Guttman's results for response rate under a variable-interval schedule.

The most noticeable increase in rate occurs from the 32.0% to the 50.0% concentration. This is a result which would not have been predicted by an extrapolation of Guttman's rate-concentration curve (1954). In fact, it is in direct opposition to earlier results by one of the present *E*s (Stebbins, 1959). The apparent disparity between this and earlier studies is probably a result of the comparatively small (0.02 milliliter) dipper used in this experiment. The depression in rate found in these earlier studies at the higher concentrations may therefore be due to satiation, as Conrad and Sidman (1956) have suggested, rather than to any aversive properties of concentrated sucrose.

Pilot work and a finer analysis of the data indicate that 4 hours is not sufficient running time for the animals' behavior to stabilize under a given concentration. This may account for the discrepancy between the two rates under the 12.7% concentration, although the χ^2 test indicates that this difference was not significant ($p > 0.05$). The slightly greater rate under the final presentation of the 12.7% concentration may be a carry-over from the high rate produced under the previous 50.0% concentration.

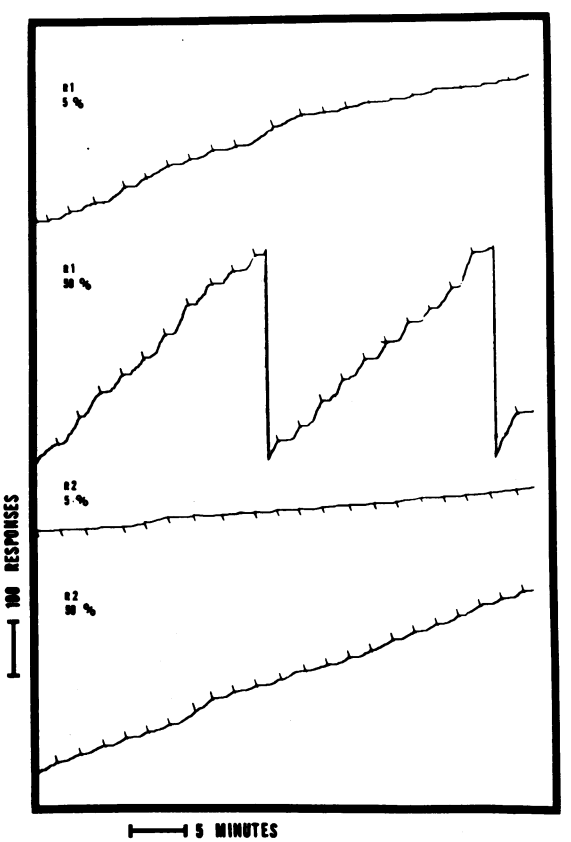

Fig. 2. Sample cumulative-response curves for both *S*s under the 5% and the 50% sucrose concentrations.

Figure 2 shows portions of the cumulative records of both animals under the 5.0 and 50.0% concentrations. These segments are from the first hour of the final session under each concentration. They demonstrate clearly the differences in behavior which occur under the two extreme concentration values.

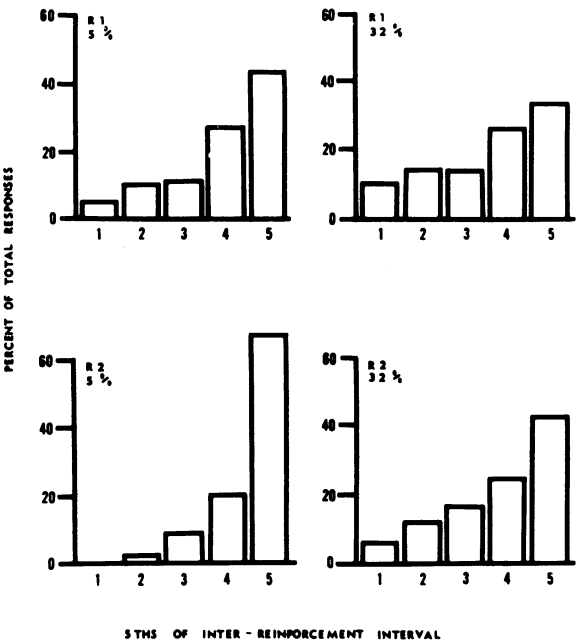

Figure 3. Percentage of total responses occurring in each fifth (24 seconds) of the 2-minute interval for both *Ss* under the 5% and the 32% sucrose concentrations.

The bar graphs in Fig. 3 provide a measure of the percentage of responses per session occurring in each fifth (24 seconds) of the inter-reinforcement interval. The sessions represent the final 2 hours for each animal under the 5.0 and the 32.0% concentration.

The comparison between the 5.0% and the 32.0% distributions has been presented, since the difference between the response distributions for these two concentrations is more pronounced than the difference between the distributions under the 5.0 and the 50.0% concentrations. The difference between the two distributions can be evaluated in terms of the percentage of responses occurring in the first and fifth parts of the inter-reinforcement interval. In general, both animals respond less frequently in the first fifth of the interval, that is, they respond less frequently immediately after reinforcement. However, they respond more frequently in the terminal segment of the interval under the 5.0% concentration than under the 32.0% concentration. This might suggest that the temporal discrimination is "sharper" under the lower concentration. However, when this same measure is applied to the response distributions with the 50.0% concentration, both animals made a slightly "better" discrimination under the 50.0% concentration compared with their discrimination under the 32.0% concentration. The reason for this finding is not known. It is possibly a function of the order in which the concentrations were presented. Or, there may be a real relationship between the shape of the distribution of responses between reinforcements and the variable of amount of reinforcement.

SUMMARY

Two food-deprived albino rats were trained under a 2-minute, fixed-interval schedule using a 12.7% (by weight) sucrose solution as reinforcement. Animals were run for 2 hours each day, and experimental days were consecutive. When stable behavior was obtained, the animals were run for 4 hours on each of four sucrose solutions. The same schedule of reinforcement was used, and the solutions were presented in the following order: 32.0, 5.0, 50.0, and 12.7%. The present evidence suggests that the function which best describes the relationship between response rate and the logarithm of the percentage sucrose concentration is exponential, within the range of values used, rather than linear, as has been previously suggested. Decreases in rate at higher concentrations which were found in earlier studies are probably due to satiation within the limits of the experimental session. Differences were found in the interval-response distributions obtained under different concentration values. Possible reasons for these differences were discussed.

REFERENCES

Conrad, D., and Sidman, M. Sucrose concentration as reinforcement for lever pressing by monkeys. *Psychol. Rep.*, 1956, **2**, 381–384.

Guttman, N. Operant conditioning, extinction, and periodic reinforcement in relation to concentration of sucrose used as reinforcing agent. *J. exp. Psychol.*, 1953, **46**, 213–224.

Guttman, N. Equal reinforcement values for sucrose and glucose solutions compared with equal sweetness values. *J. comp. & physiol. Psychol.*, 1954, **47**, 358–361.

Stebbins, W. Relation of amount of primary reinforcement to discrimination and to secondary reinforcement strength. *J. comp. & physiol. Fsychol.* (In Press)

Verhave, T. The effects of varying the concentration of a sucrose solution used as reinforcing agent in a chaining situation. Unpublished doctoral dissertation, Columbia Univer., 1955.

Received October 1, 1959