SOME NOTES ON THE CONTROL OF CONDITIONED SUPPRESSION¹

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The original study of conditioned suppression (Estes & Skinner, 1941) demonstrated that lever-pressing behavior was markedly attenuated in the presence of a stimulus that had been regularly terminated with the delivery of a brief, unavoidable electric shock. The more recent study by Stein, Sidman, and Brady (1958) indicated that the extent of suppression was inversely related to the proportion of the experimental session occupied by the shock-terminated stimulus. The absolute duration of the stimulus period or of the no-stimulus period appeared to be unrelated to the observed reduction of suppression. Rather, the amount of time spent in the period of stimulus presentation *relative* to that spent in the absence of the stimulus (i.e., "on-time/off-time") appeared to be the significant variable.

A second finding was that the number of reinforcements the animal received remained fairly constant over a wide range of variations in on-time/off-time. To quote the authors: "This finding suggested that, after sufficient training, animals will suppress in the stimulus period only to an extent that does not markedly reduce opportunities for positive reinforcement. In some interval-combination programs . . . complete suppression during the clicker period will not appreciably reduce the number of reinforcements that can be obtained in a *daily session*, as nearly all that set up in the stimulus period can be claimed shortly thereafter in the following stimulus-off period. In other programs, however, complete suppression in the clicker will markedly reduce the total number of reinforcements that can be earned in an *experimental session*."² They also suggest that the magnitude of suppression was reduced to the extent that such suppression resulted in missed reinforcements; i.e., the animal's response output varied in such a way as to minimize the loss of reinforcements.

Although not entirely clear in the article, the cited quotations and the method of estimating reinforcements missed suggest that the authors attributed the changes in suppression to changes in the *total* number of reinforcements missed. For example, an animal that receives 100 reinforcements in a 2-hour session at one on-time/off-time value may receive a total of 65 in the first session at a higher on-off ratio. It is presumably this difference (100 vs. 65 reinforcements) which is discriminated by the animal and which controls the loss of suppression in subsequent sessions. Instead of the assumption that animals discriminate between the total reinforcements accumulated during a 2- or 3-hour session, however, this discrimination could have been based on the *rate* at which reinforcements were delivered, i.e., on the number of reinforcements received in relatively short periods of time.

Insofar as the study of Stein et al. is concerned, the distinction between reinforcement rate and total reinforcements missed is a purely verbal one; if an animal's response rate varies in such a way that reinforcement rate is constant, the total number of reinforcements will also be constant if the duration of experimental sessions is fixed, as it was in this study. In a situation in which sessions are continued until a *fixed number* of reinforcements has been delivered, however, the results predicted by the two formulations are opposite.

The hypothesis that the total number of reinforcements missed controls the extent of suppression implies that suppression is independent of variations in relative stimulus-on time if experimental sessions are continued until a constant number of reinforcements has been re-

¹We are indebted to Drs. B. N. Craver and L. Stein for their helpful suggestions and criticisms.

²Italics ours.

ceived. Under these conditions, a shift from a low on-time/off-time value to a higher one should not result in a loss of suppression, since total reinforcements cannot change. On the other hand, reinforcement rate will decline to the extent that suppression increases at the higher on-off value; the hypothesis that reinforcement rate controls the extent of suppression therefore implies a subsequent loss of suppression. The experiment reported in the next section bears on these considerations.

PROCEDURE

The subjects were two adult, male albino rats maintained at 65% of their free-feeding weights. The apparatus was a sound-insulated response chamber containing a lever, a motor-driven dipper, a speaker, and a grid floor through which shocks could be delivered. Both rats were trained to depress the response lever to receive reinforcements (0.1 cubic centimeter of diluted condensed milk) on a variable-interval schedule (mean interval equal to 2 minutes). In the first phase of the experiment, 3-minute periods of tone were presented once an hour; the terminations of these were coincident with the delivery of a 1.5- to 2.0-milliampere, 0.5-second shock. In the two subsequent phases the time intervening between tone presentations (off-time) was decreased; the duration of the tone (on-time) was constant at 3 minutes. Each phase was continued until the extent of suppression was stable from day to day (about 25 sessions).

In Phase I, each session was 3 hours. In Phases II and III the sessions were continued until each animal had received a number of reinforcements equal to the mean number received in the last three sessions of Phase I. Thus, in the later phases, a rat could not "lose" reinforcements regardless of the extent of suppression. The procedures are summarized in the table in the upper portion of Fig. 1.

RAT	E-00			E-01		
PHASE	I	II	III	I	II	III
SESSION FOR:	3 hrs.	77RFT.	77RFT.	3 hrs.	84RFT.	84RFT.
ON TIME (MIN):	3	3	3	3	3	3
OFF TIME (MIN):	57	3	1	57	3	1

Figure 1. The upper portion of the figure outlines the procedural details of the experiment. The median values of tone rate/no-tone rate for each rat in the last five sessions of each phase are plotted in the lower portion.

RESULTS

The data were treated in terms of response rates (responses/minute) calculated for the tone periods (r_t) and for the no-tone periods (r_{nt}). The lower portion of Fig. 1 is a plot of the median values of the ratios of these rate measures (r_t/r_{nt}) for the last five sessions of each phase. In Phase I the ratios approach zero, indicating nearly complete suppression of lever pressing in the tone periods. As the relative amount of time that the tone sounded (on-time/off-time, on the abscissa) was increased, both rats showed losses of suppression. In both cases the curve describing these changes was an increasing, decelerating one. With Rat E-00, this function rose throughout the experiment, whereas that for Rat E-01 apparently reached a maximum in Phase II.

Since the total number of reinforcements delivered was constant throughout the experiment, the hypothesis that the total number of reinforcements missed attenuates suppression probably cannot reasonably account for these data. However, reinforcement rate could covary with changes in on-time/off-time. This finding suggests that changes in response output which minimize the decline in reinforcement rate may account for the observed loss of suppression. As previously indicated, the reinforcement-rate hypothesis can account for both the present data and those of Stein et al.

DISCUSSION

Several salient aspects of the general notion of reinforcement rate as a controlling variable should be mentioned. First, shifts in reinforcement rate are presumed to be discriminated by the animal; this suggests that some sort of a "Weber-Fechner" relationship holds. The general form of the curves in Fig. 1 bears this out in that they indicate that progressively larger increments in on-time/off-time would be required to produce equal changes in suppression. Apparently, the difference between on-off ratios of 0.53 (Phase I) and 1.0 (Phase II) is effectively greater than the differences between 1.0 and 3.0 (Phase III). The fact that Stein et al. found suppression to be a linear function of log (on-time/off-time) also supports this supposition.

Further, such a generalization probably holds true when reinforcement rate is varied directly. A study by Wilson (1954), for example, showed that as the value of the interval in a fixed-interval schedule was increased from 0 to 5 minutes, the fall in response rate was described as a decreasing, decelerating function. In general, the differences in rate were greater if small-interval rather than large-interval groups were compared. A similar curve was obtained by Kaplan (1952), who investigated intermittent reinforcement of an escape response.

These considerations lead to a second point. If the changes in reinforcement rate in part control both response rate and extent of suppression, then animals that are relatively sensitive to changes in, for example, variations in the mean interval of a variable-interval schedule should also be relatively sensitive to variations in the on-off ratios in a conditioned-suppression situation. In particular, animals showing larger decrements in response rate with decreasing reinforcement rate should show relatively greater losses of suppression with increases in on-time/off-time. Further, a change in reinforcement rate is presumably more discriminable if the preceding reinforcement rate has been high. It follows that conditioned suppression should be less if superimposed upon a schedule in which reinforcement rate has been high.

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Received March 17, 1960.