EFFECTS ON DEPRIVATION AND REINFORCEMENT- MAGNITUDE OF RESPONSE VARIABILITY¹

PETER L. CARLTON

THE SQUIBB INSTITUTE FOR MEDICAL RESEARCH

Animals were trained to displace any one of five response keys in order to put themselves in a stimulus condition in which reinforcement could be obtained by depressing a response lever. Decreased deprivation and magnitude of reinforcement were found to increase the variability of the distribution of key responses. The relevance of these findings to other experiments in which deprivation, reinforcement magnitude, and intermittent reinforcement were studied is discussed.

These experiments were designed to demonstrate the effects of changes in level of deprivation or in magnitude of reinforcement on directly measured variability of responding. The technique used to measure variability was similar to that used by Herrnstein (1961) and essentially the same as that used by Antonitis (1950, 1951) in that a two-membered response-chain was involved. The present technique differs from Antonitis' in that the terminal member of the chain was made more explicit. In particular, the programming equipment was set up so that under one stimulus condition, the animal could switch to a second condition by displacing any one of five plastic panels mounted in one wall of the response chamber. Under the second stimulus condition, and only under that condition, the animal could press a response lever in the opposite wall and thereby receive a small amount of milk. The first stimulus condition was reinstated coincident with the delivery of milk.

Level of deprivation was varied by changing the amount of food the animal was fed after each experimental session. In a subsidiary experiment, the effects of magnitude of reinforcement were briefly investigated by varying the concentration of the milk solution delivered to the animal.

METHOD

Subjects

Four adult, male, albino rats, initially maintained at about 75% of their free-feeding body weights were used.

Apparatus

A standard sound-insulated and ventilated response chamber contained a small stimulus lamp, a larger lamp (the houselight), and a speaker through which auditory stimuli could be presented was used. The chamber was 10½ in. long by 10¼ in. wide. A response lever was mounted in one wall of the chamber. Below the lever was an opening through which the cup of a motor-driven dipper could be presented. Behind the opposite wall, and ½ in. above the floor, five plastic plates were mounted. The plates were accessible to the animal through a horizontal series of five evenly spaced, 1-in. holes in the wall; the spacing between holes was 1¾ in. center to center. The animal could displace any one of the plates (response keys) and thereby activate a switch behind the plate.

The responses to the keys and to the lever were automatically recorded on a set of counters. The various response contingencies to be described were programmed by a system of relays and stepping-switches.

Procedure

Experimental sessions were conducted daily except on weekends and holidays. The animals were first trained to go to and drink from the cup at the sound of the dipper-motor (one session). They were then trained to press the lever, each press operating the dipper (one

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session); and, subsequently, (a) to respond to the lever when the small stimulus lamp was on and a clicking sound was delivered through the speaker (S_2), and (b) not to respond when the houselight was on and the clicker and the stimulus lamp were off (S_1). Details of the discrimination procedure used have been described previously (Carlton, 1959).

After the discrimination had been established, the programming circuit was arranged so that pressing any one of the five keys in S_1 switched the stimulus to S_2 ; in S_2 the first lever-press activated the dipper and reinstated S_1 . Lever-responses in S_1 were ineffective; key-responses in S_2 were recorded but had no effect on the stimulus condition.

The animals were initially "shaped" on the key-lever sequence. As needed, the center key of the five was "baited" with a drop of milk (at least once for each rat) to facilitate the acquisition of the key-pressing response. Each animal rapidly learned to displace the keys

with its nose. The terminal response sequence was: key pressing (in S_1), traversing the length of the response chamber and lever pressing (in S_2), and drinking from the cup and returning to the keys (in S_1). Each animal's session was usually continued until 200 reinforcements had been delivered.

Except as noted below, the animals were maintained at about 75% of their free-feeding weights, and the concentration of the milk (Borden's Star Brand condensed milk diluted with water) was 30%. For purposes of brevity, the details of the variations in deprivation and magnitude of reinforcement have been given below.

RESULTS

The distributions of key responding became reasonably stable after about 15 sessions. After 27 sessions at 75% body weight, the weights of all animals were shifted to 90% of their free-

Fig. 1. Distributions of key responses for four animals under four conditions of deprivation.

feeding values. Then, after nine sessions at 90%, the animals were put on a free-feeding schedule; i.e., they had free access to food in their home cages. Finally, the animals were totally deprived. The only food they received was delivered during experimental sessions. A sample set of the distributions of key responses under each of these conditions is presented in Fig. 1; the distributions were taken from Sessions 27, 32, 42, and 49. The shift from 75% to 90% body weight produced slight, if any, changes in the distribution of key responses, whereas the shift to free feeding was followed by an increase in the variability of the distributions. The increase was reversed by the introduction of total deprivation after 7-9 sessions on free feeding. Initial key-preferences were not constant throughout these variations.

One way of describing the changes in variability is in terms of the interquartile range (the range covered by the middle 50% of the responses) of the distributions obtained in each session. The interquartile ranges (IQR's) for three of the rats are plotted in Fig. 2; the

Fig. 2. Interquartile ranges for three animals under four conditions of deprivation. The squares on the abscissa indicate that the session was terminated before the usual 200 reinforcements had been delivered.

data for Rat T-02 are given separately in Fig. 3. In all rats, variability was increased (increased IQR-values) with the decrease in deprivation level induced by free feeding and,

conversely, decreased by the shift to total deprivation.

Unlike those for the other three animals, the IQR-values for Rat T-02 did not change appreciably following the changes in deprivation. This was due to the peculiar "U-shaped" distribution of the responses made by this animal. (See Fig. 1.) So long as the

Fig. 3. The number of responses to the one key to which most responses were made (as a percentage of the total number of responses to all keys) under four deprivation-conditions. As in Fig. 2, the squares on the abscissa indicate incomplete sessions.

animal made at least 25% of its responses to Key 1 and maintained a "preference" for Key 5, the IQR-values were necessarily about 3.5 regardless of any changes in the apparent variability of responding. Accordingly, the data for T-02 were treated in terms of the number of responses to the *one* key to which most responses were made, as a percentage of the total number of responses to all keys. As variability increases, the percentage made to any one key should decrease; decreased variability should be reflected as an increase in this percentage.

During the free-feeding phase, the total time required to complete the sessions increased. For example, the average number of key responses per min was 2.19 in the last four free-feeding sessions, whereas the average rate was 8.62 per min in the last four sessions of the phase in which the animals were totally deprived. In a number of instances (cf. Fig. 2 and 3), the time limitations of the experimental routine necessitated removing the animals before the usual 200 reinforcements had been delivered.

During the free-feeding phase, there was also a tendency for the animals to emit more than the one key-response required to switch stimuli. The average numbers of such "extra" key-responses (expressed as a percentage of the

total) were 3.5%, 2.9%, 21.2%, and 3.3% in the last four sessions of each successive phase of the experiment.

In the later portion of the phase in which the animals were totally deprived, the effects of decreased magnitude of reinforcement were briefly examined by reducing the concentration of milk from 30% to 1% or 3% for two of the animals. The effects of decreased magnitude of reinforcement are shown in Fig. 4. In

Fig. 4. Interquartile ranges under conditions of reduced magnitude of reinforcement (expressed as percentage concentration of condensed milk, diluted with water) for two animals. The concentration was 30% except in those sessions in which concentration was reduced to 3% or 1%.

both cases the 1% solution produced an increase in variability; the 3% solution increased variability in only one of the animals.

DISCUSSION

In general, the demonstration of changes in variability required rather drastic shifts in reinforcement-magnitude and deprivation. It

should be borne in mind that the sweetened milk used as reinforcement is a highly "preferred" substance for the rat and would therefore be expected to be an effective reinforcement even when the animals are minimally deprived of laboratory chow. That is, the technique might have been a more sensitive one had reinforcements been dry food of the kind available in the home cages. The insensitivity of the procedure may also have been due to the use of such a gross technique for categorizing responses. (Studies involving 12 more closely spaced keys are currently in progress.) Further, note that the changes in variability were gradual ones. This finding suggests that these effects were related more to changes in body weight than to the acute effects of the feeding regimen.

The effects of deprivation on variability are similar to those reported by Elliott (1934). In contrast to the present study, however, Elliott found that the changes in variability were irreversible ones.

The fact that behavior is variable may reflect an innate and clearly adaptive tendency that is effectively counteracted by reinforcement. Variables that may control such variability have been discussed by a number of writers (*eg.*, Hull, 1943; Keller & Schoenfeld, 1950; Glanzer, 1953; Thompson, 1960). Whatever the mechanisms underlying variability may be, it is to be expected that experimental manipulations that tend to maximize reinforcement will decrease variability. Three such manipulations will be briefly discussed here.

The effectiveness of a reinforcement can be most directly manipulated by reducing its magnitude. Such reductions should, and do, increase variability. Reduction to zero (*i.e.*, extinction) also results in markedly increased variability (Antonitis, 1950, 1951).

Second, shifts in level of deprivation may, as Stein has suggested (personal communication), produce correlated shifts in the effectiveness of a given magnitude of reinforcement. That is, as deprivation is decreased, the irrelevancy of the reinforcer to the animal's "need" is increased and the effectiveness of that reinforcer is accordingly decreased. This amounts to saying that food is not an effective reinforcer (*i.e.*, equivalent to zero magnitude) to the nonhungry animal and that there are intermediate levels of decreased deprivation

and correspondingly intermediate levels of effectively reduced reinforcement-magnitude.

It should also be noted that points of view (e.g., Hull, 1943; Spence, 1956) which assume that increased deprivation amplifies the differences between response tendencies would also predict increased variability with decreased deprivation, because of greater overlap of the probabilities of occurrence of the various classes of responses available.

Still a third manipulation involves the selective reinforcement of certain classes of responses. Under such circumstances, reinforcement is maximized and variability is reduced to the extent that the animal emits only those responses in the reinforced class.

Such differential contingencies could operate even though not explicitly controlled by the experimenter. In Antonitis' study (1950, 1951), for example, variability of responding increased during extinction following continuous reinforcement. When reconditioned, variability of responding was found to be less than that which had characterized the pre-extinction period and less than that of a control group that had not undergone extinction. It may have been that response tendencies that were greater during the initial continuous reinforcement session underwent relatively less weakening during the extinction sessions. This would be especially likely if, during extinction, initially nondominant responses were emitted about as often as the initially dominant ones. Examination of Antonitis' data (1950) indicates this was the case.

If such contingencies were in fact operative, it would be expected that the initial dominance of particular responses would be maintained and accentuated in the reconditioning phase. According to Antonitis (1960, p. 56): "The modal values of position distributions yielded by both experimental and control group animals in reconditioning sessions coincide closely with modal values of distributions on the fifth day of conditioning. . . ." Since the variability of responding of the experimental group was reduced, there would necessarily have been a relative increase in the frequency of initially preferred responses.

Such an "accentuation of preference" may also be seen in data reported by Herrnstein (1961). In this study, pigeons pecked at a rubber strip and, under continuous reinforcement for all responses, showed marked position pref-

erences. The animals were subsequently switched to a variable-interval schedule. On this schedule the probability of nonpreferred responses occurring would be low and, therefore, the probability of their being reinforced extremely small. As expected, Herrnstein found that the relative frequency of occurrence of the initially preferred response increased, whereas that of nonpreferred responses decreased.²

The preceding point of view is essentially the same as that advanced by Weinstock (1958) in his discussion of the effects of partial reinforcement on subsequent extinction. The relevance of the present considerations to these effects will not be elaborated here.

As a final point, it is reasonable to suppose that the consequence of the three manipulations discussed should also affect the variability of responding in other components of the total behavior of the animal. Thus, in the present study, the times required to traverse the response chamber increased as variability of key responding increased, presumably because of the intrusion of time-consuming, irrelevant responses into the chain involved in moving between keys and lever. Similarly, the frequency of extraneous, "extra" key-responses increased under low deprivation. Other experimenters have reported related effects of reduced deprivation (Cotton, 1953) and of reduced magnitude (Pereboom & Crawford, 1958). Finally, the relatively greater weakening of nondominant responses has been advanced to account for the effects of repeated extinction and conditioning in a situation in which a jumping stand was used (Lauer & Estes, 1955).

REFERENCES

- Antonitis, J. J. Variability of response in the white rat during conditioning and succeeding extinction and reconditioning. Unpublished doctoral dissertation, Columbia Univer., 1950.

²Intermittent reinforcement apparently has this effect on the extensive, but not the intensive, characteristics of responding. The variability of forces exerted by rats in pressing a lever has been found to increase when the reinforcement schedule is switched from continuous to fixed-interval (Goldberg, 1959). In contrast, changes in variability of forces during extinction and reconditioning were found (Goldberg, 1959; Notterman, 1959) to parallel those obtained by Antonitis. Related studies involving the duration of the lever response are in progress in this laboratory.

- Antonitis, J. J. Response variability in the white rat during conditioning, extinction and reconditioning. *J. exp. Psychol.*, 1951, **42**, 273-281.
- Carlton, P. L. Discrimination learning. *Science*, 1959, **130**, 1341-1343.
- Cotton, J. W. Running time as a function of amount of food deprivation. *J. exp. Psychol.*, 1953, **46**, 188-198.
- Elliott, M. H. The effect of hunger on variability of performance. *Am. J. Psychol.*, 1934, **46**, 107-112.
- Glanzer, M. Stimulus satiation: An explanation of spontaneous alternation and related phenomena. *Psychol. Rev.*, 1953, **60**, 257-268.
- Goldberg, I. A. Relations of response variability in conditioning and extinction. Unpublished doctoral dissertation, Columbia Univer., 1959.
- Herrnstein, R. J. Stereotypy and intermittent reinforcement. *Science*, 1961, **133**, 2067-2069.
- Hull, C. L. *Principles of behavior*. New York: Appleton-Century-Crofts, 1943.
- Keller, F. S., and Schoenfeld, W. N. *Principles of psychology*. New York: Appleton-Century-Crofts, 1950.
- Lauer, D. W., and Estes, W. K. Successive acquisitions and extinctions of a jumping habit in relation to schedule of reinforcement. *J. comp. physiol. Psychol.*, 1955, **48**, 8-13.
- Notterman, J. M. Force emission during bar pressing. *J. exp. Psychol.*, 1959, **58**, 341-347.
- Pereboom, A. C., and Crawford, B. M. Instrumental and competing behavior as a function of trials and reward magnitude. *J. exp. Psychol.*, 1958, **56**, 82-85.
- Spence, K. W. *Behavior theory and conditioning*. New Haven: Yale Univer. Press, 1956.
- Thompson, M. E. A two-factor theory of inhibition. *Psychol. Rev.*, 1960, **67**, 200-206.
- Weinstock, S. Acquisition and extinction of a partially reinforced running response at a 24-hour intertrial interval. *J. exp. Psychol.*, 1958, **56**, 151-158.

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