Amount of training and reversal learning with singly presented stimuli in the rat

A. P. GREENWAY

University of Aberdeen, Old Aberdeen, Scotland AB9 2UB

In a discrete trials multiple reversal experiment with singly presented stimuli, rats were given either 10 or 20 training trials per day for 2 days on each problem. All subjects improved progressively over reversals, but subjects with more training on each problem showed greater inhibition of responding to S— during reversal than those having less training. For both groups, the S— within sessions curve became steeper over reversals. Inhibition of responding to S— was greater on Day 2 of a reversal than on Day 1. The rat data are discussed in relation to those obtained from pigeons and goldfish.

Recent experiments on multiple discrimination reversals employing singly presented stimuli in discrete trial situations in the pigeon and goldfish (Woodard & Bitterman, 1972; Woodard, Schoel, & Bitterman, 1971) have revealed that improvement over reversals is due to two changes, both predominantly inhibitory in character and controlled by the negative stimulus (S—). First, the tendency not to respond to the previously negative stimulus initially carries over from one reversal to the next causing initial responses to the now positive stimulus (S+) to be slow (negative transfer). This carryover decreases as a function of number of reversals. Second, the tendency to respond to S— decreases within each daily session, and the rate of decrease accelerates over reversals. The performance of the rat in a comparable experimental situation is not documented in detail (Khavari & Heise, 1967).

Bitterman suggests that improvement in reversal learning performance with both simultaneous (Bitterman, 1969) and singly presented stimuli takes place because, in the course of a series of reversals, the animal gradually ceases to transfer what it learns during one reversal, i.e., to respond to S+ and not to S—, to the next reversal. This decline in transfer is caused by proactive interference. In practice, this means that what the animal learned during a given reversal, e.g., Reversal 4, interferes later with its retention of what it learned on the next reversal, e.g., Reversal 5. Over a series of reversals, this interference accumulates and eventually the animal does not respond according to the response contingencies of the immediately previous session at the start of the next reversal (Woodard et al., 1971).

Data from pigeons on successive reversal learning in an operant situation reported by Beale (1970) also are relevant to the present study. They showed that despite large variations in amount of training, all animals

improved on successive reversals because of the increased rate of extinction of their response to the new S— during reversal. Hence, considerable decrease in negative transfer occurred. This experiment also showed that the greater the amount of training, the better the discriminative performance to both S+ and to S—, a finding well known in choice situations (Gonzalez, Berger, & Bitterman, 1966). In the context of the proactive interference hypothesis (PI), this positive relationship of amount of training to discriminative performance is difficult to interpret. It might indicate, e.g., that animals having more training per session were better able to establish the preferences required by the current reversal because the extinction of previously learned preferences was more nearly complete.

The present experiment was designed to gather data for the rat comparable to that obtained with the pigeon and goldfish and to assess the effect of amount of training both on the animal's ability to differentiate between S+ and S— over reversals and on negative transfer in early reversals.

METHOD

Subjects

The subjects were 22 naive male hooded Listar rats, about 90 days old at the beginning of the experiment. They were maintained on a 24-h feeding schedule at 90% of their ad-lib weights.

Apparatus

A modified Lashley jumping stand was used. The jumping platform was removed, and the partition dividing the two stimuli was extended outward to a length of 92 cm. A single elevated arm, 6.4 cm wide and 76.8 cm long, was placed in parallel with, and 5.1 cm from, the extended partition. This elevated approach arm stopped 10.2 cm short of the stimulus door (the right stimulus of what was the Lashley jumping stand). A subject could thus be placed on the end of the approach arm furthest from the stimulus door, and the time elapsing before it touched the stimulus door could be measured. As in the orthodox Lashley jumping stand, when S+ was presented, the door was easily pushed over by the subject; when S— was presented, the door was fastened.

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Figure 1. Mean log response times (seconds) for the 10-trial and 5-trial groups as a function of trials per session early and late in training.

Procedure

The subjects were given four 2-min periods per day for 2 days in the apparatus without stimulus doors but with food present in the goalbox; they then were trained with a mid-gray stimulus to approach and push over the door to get food. Reward throughout the experiment was four 45-mg Noyes pellets. The subjects were then divided into two groups of 11 each, a 10-trial group which received 10 trials of S+ and 10 of S- each day and a five-trial group which received five trials of S+ and five of S- each day. In each group, six subjects began with a black door as S+ and a white door as S- and five subjects with the reverse arrangement. Two days of training were given on each problem before the reinforcement contingencies associated with stimuli were switched for the next reversal. There were 20 problems.

Latency from placement on the end of the elevated arm to touching the stimulus door was recorded on each trial. If the subject did not touch the stimulus door within 30 sec on S- trials, it was removed from the apparatus, and a score of 30 sec was recorded.

RESULTS

An analysis of variance (Reversals by Days by Stimuli by Trials) was carried out on the data for the whole of training for each group. The data are shown in Figure 1. The major finding, subjects' responding less slowly to S-

Figure 2. Mean log response times (seconds) for the 10-trial and 5-trial groups as a function of reversals.

on Day 1 than on Day 2, was clearly reflected in several interactions. For the 10-trial group, these were Days by Stimuli ($F = 166.90$, $df = 1/10$, $p < .01$), Reversals by Days by Stimuli ($F = 3.03$, $df = 19/190$, $p < .01$) and Days by Stimuli by Trials ($F = 3.75$, $df = 9/90$, $p < .01$). For the five-trial group, the effect was apparent in the Days by Stimuli interaction ($F = 75.89$, $df = 1/10$, $p < .01$). From R, 0-1 onwards, the 10-trial group ran more slowly to S- on Day 2 than on Day 1. The five-trial group established this pattern only around R, 5-6. Once established, this difference remained fairly stable in both groups throughout the whole of training.

Early in training, the amount of negative transfer declined in the 10-trial group. Tukey tests were performed on the differences between the means for the Reversals by Days by Stimuli interaction for R, 0-5. For R, 0-2, but not after R, two of the animals ran more slowly to S+ and more quickly to S- on Day 1 of a reversal than they had on Day 2 of the previous reversal. (For S-, R, 0-1, $p < .01$; R, 1-2, $p < .05$; for S+, $p < .01$ for both differences.) Tukey tests performed on the differences between means for Days 1 and 2, for S+, R, 0-4 also confirmed that the 10-trial group ran more quickly to S+ on Day 2 of these reversals than on Day 1 ($p < .01$ for all differences). After R, four no significant differences were found.

Separate analyses of variance performed for each group on the data for R, 14-15; -R, 19-20, produced significant Days by Stimuli interactions ($F = 9.37$,

$df = 1/10$, $p < .05$ for the 10-trial group and $F = 25.65$, $df = 1/10$, $p < .01$ for the five-trial group), a significant days by stimuli by trials effect for the 10-trial group ($F = 2.30$, $df = 9/90$, $p < .05$), but not for the 5-trial group ($F = 2.46$, $df = 4/40$, $p > .05$). This indicates that the difference between days for the five-trial group involved a difference in level of responding to S- over trials. Since subjects responded rapidly to both stimuli at the outset of each session, this finding of differences in levels of S+ and S- cannot be attributed to a simple carryover from S- and from S+, respectively, of the preceding reversal.

The number of trials per session (5 vs. 10) affected the development of differential response tendencies to S+ and S-. These data are shown in Figure 2 as a function of reversals. The means of the S+ and S- trials for Days 1 and 2 of R, 19-20 for both groups were submitted to analysis of variance. The Groups by Stimuli interaction was significant ($F = 20.89$, $df = 1/20$, $p < .01$). Tukey tests performed on the differences between means for S+ and S- between groups showed that the 5-trial group ran more quickly to S- than the 10-trial group ($p < .01$). The groups did not differ significantly in their response to S+.

DISCUSSION

The results of the present experiment on the rat do not wholly support the PI account of improvement in

reversal learning. The behavior of the 10-trial group at the outset of a reversal does favor this view. Early in training on the initial trials of a problem subjects seemed to respond in terms of the cue contingencies of the previous problem (negative transfer). Later in the initial trials of a session, however, subjects responded rapidly to both stimuli before beginning to respond slowly to S-. This finding has been consistently reported in previous work on the rat (Khavari & Heise, 1967), goldfish and pigeon (Woodard & Bitterman, 1972; Woodard et al., 1971).

Throughout training, both groups responded more slowly to S- (and therefore more differentially with regard to S+) on Day 2 than on Day 1. This finding does not support the PI theory. If subjects forgot between days what they learned on Day 1, they did not do so completely even at the end of training nor did they do so at an increasing rate over the 20 or so reversals of the experiment.

Differences in asymptotic performance of pigeons between Days 1 and 2 of a reversal were reported by Woodard et al.; these were due to rapid development of withholding of responses to S- on Day 2. The present experiment and that of Woodard et al. were not entirely similar: in the pigeon experiment, subjects received twice as many trials per day as the rats in the present experiment. Differences between Days 1 and 2 reported here may therefore be due to subjects' failure to establish completely on Day 1 the preferences required by a particular reversal. This implies that the subjects did not reach asymptote in respect to their Day 1 performances. Thus, had they been given more training per day, the differences between Day 1 and Day 2 in respect of S- might have been eliminated or have been confined to the early trials of Day 2 and have appeared as a difference in rate of inhibition growth and not as an overall difference in level of inhibition.

The number of trials per day was clearly a critical variable, being positively related to the asymptotic level of responding to S-. In choice experiments in the rat, increased amount of training (number of days per reversal) causes an increase in negative transfer (carryover in inappropriate preferences from one session to the next) early in training. (Gonzalez, Berger, & Bitterman, 1966). In the present experiment, it produced a greater inhibition of response to S- (cf. Figure 2). This finding is consistent with the idea that progressive improvement in reversal learning is due in some measure to an increase in the rate of within reversal learning. Thus, the effect of greater amounts of training within sessions could be an increase in the probability that subjects attend to the relevant stimulus

dimension. (Mackintosh & Mackintosh, 1964). There is an alternative interpretation equally consistent with the data. The difference between groups in speed of response to S- could simply be a difference in inhibitory response strengths.

The description of unitary discrimination reversal learning as largely inhibitory in character for pigeons and goldfish (Woodard & Bitterman, 1972; Woodard et al., 1971) is not wholly true for rats. Excitatory tendencies are also involved. First, in the early reversals, the 10-trial group showed greater excitatory tendencies on Day 2 than they had on Day 1. The effect is partially masked in the five-trial group, probably because of an increase in their speeds of response to both stimuli. Second, the increase in differentiation between S+ and S- over reversals is as much attributable to growth in the overall level of excitation as it is to growth in inhibition.

The interaction of positive and negative transfer may be an important component of an explanation of improvement in unitary reversal situations. The data from both groups suggest how such an interaction might occur. Clearly, insufficient training was given on R₁ to counteract completely the negative transfer originating in R₀. Thus, the subjects entered R₂ with weak habits from R₁ and a residue of not entirely forgotten preferences from R₀ which were strengthened in R₂. The residual effects of R₁ then were strengthened in R₃. Amount of practice given each day has two functions, therefore, to counteract negative transfer and to establish current required preferences.

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