A role of stimulus compounds in eliciting responses: Relatively spaced extinction following massed acquisition

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One of two schedules of rewarded (R) and nonrewarded (N) trials (RNR vs. RRN) was combined factorially with intertrial interval (ITI) in acquisition (1 vs. 45 min), with extinction occurring at a 45-min ITI. The RNR schedule produced greater resistance to extinction than the RRN schedule regardless of acquisition ITI. The shift in ITI from acquisition to extinction reduced resistance to extinction slightly in the RNR group but not in the RRN group. These findings suggest that there are cues common to 1-min and 45-min ITIs. It was suggested that these ITI-associated cues enter into compound with memories to control instrumental responding.

A change in intertrial interval (ITI) from acquisition to extinction reduces resistance to extinction and reduces or eliminates reward-schedule effects such as the partial reinforcement extinction effect (Amsel, Wong, & Traupmann, 1971; Capaldi, Berg, & Sparling, 1971; Capaldi & Morris, 1974; Lewis & Cotton, 1959; Teichner, 1952). Collectively, these findings indicate (see Capaldi & Morris, 1974) that massed trial responding is controlled by stimulus traces (STrs) produced by reward and nonreward, that not only are unique stimuli associated with highly massed trials (the STrs) but with Trial 1 of the day (ST1) as well, and that memories such as the memory of nonreward (S^N) enter into compound with STr and ST1 to regulate instrumental responding.

According to Capaldi and Morris (1974), if, as under massed trial partial reinforcement, the stimulus compound S^N + STr acquires associative control over the instrumental reaction, then the stimulus compound S^N + ST1 which occurs in extinction at a 24-h ITI will possess but little capacity to elicit the instrumental reaction, and vice versa. The role of the stimulus compounds in eliciting responses cannot be stressed too greatly; it is the compounds and not S^N alone which elicit responses in acquisition and extinction. Moreover, ITI-associated cues such as STr and ST1 are retrieval cues for memories such as S^N , and thus these cues determine, in combination with other retrieval cues such as alley cues, on what particular trials S^N will be present, i.e., retrieved. For example, if nonreward occurs on Trial 1 of the day, i.e., S^N is stored in the presence of ST1, then S^N will be better retrieved on Trial 1 of the following day, when ST1 is presented again, than on Trial 2 of the same day, where ST1 is absent, and STrs are present (see Capaldi & Morris, 1974). That S^N stored on Trial 1 may be better retrieved on Trial 1 of the following day than on Trial 2 of the same day is

perhaps counterintuitive, but it is consistent with recent findings (Capaldi & Morris, 1974) as well as with the view that not the passage of time per se, but the absence of retrieval cues, is the basis of forgetting (e.g., Capaldi, 1971; Tulving, 1974).

Granting that memories such as S^N always enter into compound with ITI-associated cues such as STr and ST1 to control responding, and that STr and ST1 act as retrieval cues for S^N , it follows that in order to understand responding at a particular ITI, it is necessary to determine if unique cues are associated with that ITI. However, since shifts in ITI from acquisition to extinction have only occurred from or to a 24-h ITI (e.g., Amsel et al., 1971; Capaldi et al., 1971; Mackintosh & Little, 1970) or from one to another relatively short ITI (e.g., Lewis & Cotton, 1959; Teichner, 1952), information is lacking as to what unique cues, if any, are associated with trials sufficiently spaced so that STrs are not present, but neither are the ST1 cues, since the ITI is less than 24 h. This matter was of concern in the present investigation, in which rats given acquisition training at a 1-min ITI were subsequently extinguished at a 45-min ITI.

In this investigation, groups received a schedule of rewarded (R) and nonrewarded (N) trials which either contained (Group RNR) or did not contain (Group RRN) a daily transition from N to R trials. Two findings concerning the effects of these schedules on extinction are noteworthy here; if training and extinction occur at a relatively short ITI, RNR groups show much greater resistance to extinction than RRN groups (e.g., Capaldi & Lynch, 1968), but if training occurs at a short ITI followed by extinction at a 24-h ITI, the RNR schedule will produce no greater resistance to extinction than the RRN schedule (Mackintosh & Little, 1970). Of concern here were the effects of extinguishing RNR and RRN groups at a 45-min ITI following training at a 1-min ITI. Also included in this investigation were RNR and RRN groups trained and extinguished at a 45-min ITI.

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METHOD

Subjects

The 40 male albino rats, approximately 130 days old at the beginning of the experiment, were purchased from Holtzman Co., Madison, Wisconsin.

Apparatus

The apparatus was a runway 208.4 cm long x 22.0 cm high and 10.2 cm wide with a hinged lid of 1.3-cm hardware cloth and a wood floor. The alley was divided into three sections. The first section consisted of a treadle 20.3 cm long, suspended above a microswitch. By placing the front paws of the rat on the forward edge of the treadle, the first clock (.01 sec) was started. Interruption of a photobeam 5.1 cm beyond the treadle stopped Clock 1 (start time) and activated Clock 2 (run time). Interruption of a photobeam 132.1 cm beyond the first photobeam stopped Clock 2 and activated Clock 3 (goal time). The goal clock was stopped when a photobeam 39.4 cm beyond the second photobeam and 6.4 cm in front of a 5.1 x 10.2 x 3.8 cm food tray was broken. Within the food tray was a 3.8 x 3.2 x 1.9 cm metal foodcup which was positioned on the right side of the food tray. A brass guillotine door, 30.5 cm from the end of the runway, was manually lowered to prevent retracing once an animal had interrupted the third photobeam.

Procedure

Upon arrival at the laboratory, the subjects were maintained on ad lib diet for approximately 40 days. Water was always available in the home cages. On Day 1 of the experiment, all food was removed from the subjects' cages. Throughout the remainder of the experiment, subjects were maintained on a 13-g/day deprivation schedule. On Day 10 and each of the 2 following days, subjects were handled in squads of four for 4 min/squad. After the daily handling session, subjects were returned to the home cages where they received a glass casket containing 15 .045-g Noyes pellets. On Day 13, subjects were randomly assigned to one of four treatment groups defined by the factorial combination of acquisition ITI and acquisition sequence. The two acquisition ITIs were 1 min and 45 min, while the sequences were defined by whether R trials followed N trials within a day (RNR condition) or by whether all N trials followed all daily R trials (RRN condition). Ten subjects were assigned to each of the

four treatment groups. The 1-min ITI groups (Group RNR-1 and Group RRN-1) were run in squads of two, one from each sequence condition. The running order within each squad was randomly determined each day. The subjects in a squad were then run alternately until all trials of a day were completed. This squad rotation produced an ITI of about 1 min. Running order between squads was the same each acquisition day. The 45-min ITI groups (RNR-45 and RRN-45) were rotated such that all 20 subjects in this condition finished a trial before the rotation was begun again. Each acquisition day, subjects were randomly assigned a running order within squads of two, one subject representing each sequence condition such that the subjects in Squad 1 were assigned Running Orders 1 and 2, and subjects in Squad 2 were assigned Running Orders 3 and 4, and so forth, until all 20 subjects were assigned an order. This rotation would normally produce an ITI of less than 45 min, so the experimenter did not begin the next rotation until 45 min had elapsed.

The two acquisition sequences were administered for 10 days. The subjects in the RNR condition received the following order of R and N trials (where a comma separates days): RNR, RNRNR, RRNR, RNR, RNRNR, RRNR, RNR, RRNR, RNR, and RRNR, while subjects in the RRN condition received RRN, RRRNR, RRNR, RRNR, RRRNR, RRNR, RRNR, RRNR, RRNR, and RRRNR. It should be noted that these two sequence conditions are equated for number of trials, number of R trials, and number of N trials on both a daily and an overall basis. The only difference between the conditions is the sequence of R and N trials. On all R trials, subjects were administered 15 .045-g Noyes pellets and remained in the goalbox until all pellets had been consumed. On N trials, subjects were confined in the goalbox for 30 sec.

Beginning the day after the last day of acquisition training, extinction was administered at a rate of five trials per day for 4 days. Each squad of two subjects in acquisition was combined with the same numbered squad from the other ITI condition. Daily running orders were randomly assigned within these new squads of four subjects such that the subjects in Squad 1 were assigned Orders 1-4, the subjects in Squad 2 were assigned Orders 5-8, and so forth. All 40 subjects received a trial in rotation prior to the next rotation. The ITI was not allowed to fall below 45 min. Nonreward confinement duration remained at 30 sec.

RESULTS

The times recorded from each alley section were converted to speeds (1/sec) and all analyses were performed on these speeds. Since the run and goal sections produced similar results and the start section revealed no significant differences attributable to the experimental variables, only the goal-section findings will be presented here.

On the last day of acquisition, Group RRN-1 appeared to be running faster than the other three groups. Analysis of variance revealed, however, that sequence [$F(1,36) = 2.25, p > .10$], ITI [$F < 1.0$], and the Sequence by ITI interaction were not significant ($F < 1$).

The mean goal speed on the last day of acquisition and the goal speeds for each trial of extinction for the four experimental conditions are shown in Figure 1. Examination of Figure 1 reveals that the RNR groups ran faster in extinction than the RRN groups. Too, the differences between the 1-min acquisition ITI groups was smaller on Days 1 and 4 than the differences between

Figure 1. Mean goal speed for the four experimental groups for the last day of acquisition and each trial of the 4 days of extinction.

the 45-min acquisition ITI groups. While the smaller difference on Day 1 may be attributed to terminal acquisition differences between Groups RNR-1 and RRN-1, it is clear that reduced differences on Day 4 are due to the slow responding of Group RNR-1 as compared to Group RNR-45.

In an earlier or "pilot" version of this investigation, extinction differences between Groups RNR-1 and RNR-45 developed as shown in Figure 1; the two groups differed little on early extinction days and then, as on Day 4 in Figure 1, Group RNR-1 ran very slowly relative to Group RNR-45. Given these preliminary findings, it was decided to statistically analyze each day of extinction separately.

A 2 (sequences) by 2 (ITIs) by 4 (trials/day) analysis of variance was performed on each extinction day. Trial 1 of each day was excluded since it did not reflect performance under a 45-min ITI. That the RNR groups were more resistant to extinction than the RRN groups was revealed by significant sequence effects on Day 2 [$F(1,36) = 19.15$, $p < .001$], Day 3 [$F(1,36) = 13.72$, $p < .005$] and Day 4 [$F(1,36) = 9.67$, $p < .005$]. On Day 1, the sequence effect was marginally reliable [$F(1,36) = 3.88$, $p < .06$]. Individual comparisons of the effect of sequence at each ITI revealed that Group RNR-45 ran faster than Group RRN-45 on all 4 extinction days [smallest $F(1,36) = 5.85$, $p < .05$] while Group RNR-1 was significantly faster than Group RRN-1 on Day 2 [$F(1,36) = 6.49$, $p < .05$] and Day 3 [$F(1,36) = 8.11$, $p < .005$] but not on Days 1 and 4 ($F_s < 1$). That the N-R sequence effect was smaller for the 1-min ITI groups than for the 45-min ITI groups was indicated by a significant Sequence by ITI interaction on Day 4 of extinction [$F(1,36) = 4.96$, $p < .05$]. Simple effects of this interaction further indicated that Group RNR-1 was significantly less resistant to extinction than was Group RNR-45 [$F(1,36) = 7.78$, $p < .01$] while the RRN groups did not differ ($F < 1$).

DISCUSSION

The present findings that Group RNR-1 showed a slight, but not a substantial, decrease in resistance to extinction, and that Group RNR-1 was more resistant to extinction than was Group RRN-1 suggests that a 1-min ITI and a 45-min ITI are not entirely dissimilar, and that the two ITIs share cues in common. In keeping with prior usage (Capaldi & Morris, 1974), the cues common to ITIs diverse as 1 min and 45 min are called cues common to massed trials and are symbolized as SMT. While the basis of the SMT cues is at this time a matter of conjecture, it is possible to identify events which may not lie at the basis of the SMT cues. The SMT cues would not seem to be STRs produced by reward and nonreward, for by common agreement such STRs are not considered to remain active for so long as 45 min (e.g., Amsel, 1967; Hull, 1952; Rothkopf, 1955; Sheffield, 1949; Teichner, 1952). Of course, if

subsequent data indicated the STRs produced by reward and nonreward do remain active for as long as 45 min, then the hypothesis that STRs are at the basis of the SMT cues would be tenable. We shall, however, treat STRs and SMT cues separately here. In any event, in the Mackintosh and Little (1970) investigation, RNR and RRN groups trained at a 30-sec ITI failed to differ in spaced (24 h) extinction. Thus, the SMT cues must be reasonably dissimilar from the ST1 cues, for if this were not so, then Groups RNR-1 and RRN-1 of this investigation would have failed to differ in extinction at a 45-min ITI as did the RNR and RRN groups of Mackintosh and Little (1970) shifted to a 24-h extinction ITI. On the basis of available ITI-shift findings, then, three sorts of ITI-associated cues may be identified, STRs produced by reward and nonreward which are present only at highly massed trials, ST1 cues which are present only on the first trial of the day, and SMT cues which appear to be present on all trials of the day except Trial 1 and which may be relatively independent of within-day ITI. Employing these cues, let us apply the memory model (e.g., Capaldi & Morris, 1974) to the different results obtained by Mackintosh and Little (1970) and in the present investigation.

The tendency to resist extinction at a 24-h ITI depends upon the capacity of the stimulus compound $S^N + ST1$ to elicit the reaction. In neither Group RNR nor Group RRN employed by Mackintosh and Little (1970) did the stimulus compound $S^N + ST1$ acquire in acquisition any appreciable tendency to elicit the instrumental reaction. The within-day ITI in the Mackintosh and Little investigation was 30 sec. Thus, in both Group RNR and Group RRN, S^N was stored in the presence of STr + SMT and thus in neither group would S^N be appreciably retrieved by ST1 or on the first trial of the subsequent day. In neither group, then, did S^N occur strongly in compound with ST1 in acquisition, and thus the introduction of the $S^N + ST1$ stimulus compound in extinction failed to elicit the reaction with any degree of vigor in either of the groups. In an investigation by Capaldi and Lynch (1968), an RNR group was more resistant to extinction than an RRN group when training and extinction occurred at a 3-min ITI. Assuming that STRs are present at a 3-min ITI, the tendency to resist extinction at that ITI would depend upon the capacity of the stimulus compound $S^N + STr + SMT$ to elicit the reaction. In Group RNR S^N was stored in the presence of STr and SMT on Trial 2 of the day, and this stimulus compound was conditioned to the instrumental reaction on Trial 3 of acquisition days. However, there is no acquisition trial for Group RRN on which the stimulus compound $S^N + STr + SMT$ can occur and be conditioned to the reaction. Thus, Group RNR showed greater resistance to extinction than did Group RRN at a 3-min ITI.

The tendency to resist extinction at a 45-min ITI depends upon the capacity of the stimulus compound $S^N + SMT$ to elicit the reaction. This stimulus

compound was conditioned to the instrumental reaction in Group RNR-45 on rewarded trials which followed nonrewarded trials, but the compound $S^N + SMT$ was not conditioned to the instrumental reaction in acquisition in Group RRN-45, because there was no acquisition trial on which this compound occurred for Group RRN. Accordingly, Group RNR-45 showed greater resistance to extinction than did Group RRN-45. In Group RNR-1, the stimulus compound conditioned to the instrumental reaction in acquisition on rewarded trials which followed nonrewarded trials was $S^N + STr + SMT$; this compound was not conditioned to the instrumental reaction in Group RRN-1, because on no trial did this compound occur in Group RRN-1 in acquisition. In order to understand the considerable resistance to extinction of Group RNR-1, then, it need only be assumed that if the stimulus compound $S^N + STr + SMT$ is conditioned to the instrumental reaction, then the compound $S^N + SMT$ will elicit the instrumental reaction with considerable vigor. That Group RNR-1 was slightly less resistant to extinction than was Group RNR-45 was presumably due to the fact that, whereas Group RNR-45 was extinguished in the presence of the stimulus compound which had directly acquired control over the instrumental reaction in acquisition ($S^N + SMT$), in Group RNR-1 the extinction compound ($S^N + SMT$) differed slightly from the compound conditioned to the response in acquisition ($S^N + STr + SMT$). The effects in extinction in Group RNR-1 of removing STr from the stimulus compound were quite evidently slight, inasmuch as Group RNR-1 was not much less resistant to extinction than was Group RNR-45. The effect is much greater, of course, when, as in the Mackintosh and Little investigation, an RNR group was extinguished at a 24-h ITI, for at a 24-h extinction ITI, not only are both STr and SMT removed from the stimulus compound but STI is introduced in compound along with S^N , as well. The present model is consistent with all extinction findings which have been reported for RNR vs RRN groups. Moreover, it is consistent with other ITI-shift findings which have been reported (see Capaldi & Morris, 1974).

In many instances, neither ITI nor apparatus cues nor other cues change meaningfully from one trial to the next, and in such cases it is irrelevant to the predictions of the model employed whether or not the stimulus compounds which control behavior are emphasized. Thus, for example, the predictions of the memory model are not altered for, e.g., a partially rewarded group which is trained and extinguished at a 24-h ITI no matter if the compound $S^N + STI$ is emphasized or merely S^N is emphasized. However, when, as in the present investigation, ITI is changed from acquisition to extinction, it becomes necessary to specify precisely and in detail the total stimulus compound which controls responding. Accordingly, one of the major contributions

of ITI-shift findings to contemporary theory may lie in forcefully bringing to attention that memories such as S^N always enter into compound with whatever other cues may be available to control instrumental responding. For example, on the basis of within-subjects partial-reinforcement findings (see Capaldi, 1971; Capaldi & Morris, 1974; Mellgren & Dyck, 1972; Mellgren, Dyck, Seybert, & Wrather, 1973), it is clear that in discrimination learning situations S^N enters into compound with visual cues, e.g., black alley vs. white alley, to control instrumental responding. Indeed, Burstein and Moeser (1971) have demonstrated that brightness cues enter into compound with STI cues to regulate instrumental behavior. Thus, that stimulus compounds are not always emphasized, as here, means only that in many cases such specification is not necessary. Clearly, however, such specification is important, for a model which can explain, e.g., a partial reinforcement extinction effect when the ITI is the same in extinction as in acquisition may not be able to explain the effects of an ITI shift on the partial reinforcement extinction effect. Generally speaking, then, ITI-shift findings appear to demand a more precise specification of the stimuli controlling behavior.

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