Effects of reinforcement history on the mediation of human DRL performance

NORMAN STEIN

Syracuse University, Syracuse, New York 13210

Human subjects provided with a history of FR 20 conditioning exhibited less efficient performance and higher rates of collateral behavior during subsequent DRL 5-sec training than subjects who received a previous history of FI 10-sec/cost conditioning. Removal of the opportunity to engage in collateral behavior produced a disruption in temporally spaced responding only with the FR pretrained group. The findings indicate that the conditioning history is an important determinant of the manner in which humans mediate a temporally spaced (DRL) schedule of reinforcement.

Previous research (e.g., Bruner & Revusky, 1961; Carter & MacGrady, 1966) has shown that human subjects performing on a differential reinforcement of low rates (DRL) schedule tend to engage in unscheduled repetitive chains of collateral behavior during the inter-response times (IRTs). Stein and Landis (1973) demonstrated that the collateral behavior represents a form of superstitious behavior which serves a mediating function by regulating the rate of temporally spaced reinforced responding. The rate of temporally spaced responding has also been shown to be related to the subject's reinforcement history. Singh (1971) and Weisberg (1970) found that fixed-interval (FI) conditioning histories, which produce relatively slow response rates, facilitate the subsequent acquisition of efficient DRL performance and that fixed-ratio (FR) reinforcement histories, which support relatively faster response rates, serve to interfere with the efficiency of subsequent DRL performance. The present study was designed to extend the understanding of these transfer effects by analyzing the influence of FI and FR conditioning histories on the collateral behavior which mediates human DRL performance.

METHOD

Subjects

The subjects were 20 female introductory psychology students who received class credit for participation and were chosen from classes in which reinforcement schedules and related material had not been discussed.

Apparatus

Each subject was seated before a chassis containing four adjacent telegraph keys placed 9.5 cm apart and requiring a downward force of 440 g to be electrically recorded as a response. Directly above each key was a separate white light which could be operated remotely. Two four-digit add counters were mounted in the middle of the chassis. The upper counter indi-

cated cumulative number of points (reinforcements) in 10-point increments, and an amber light directly above this counter flashed momentarily to indicate the activation of the counter. Accumulation of points has been shown to be an effective reinforcer for college students participating in an experiment to fulfill a course requirement (e.g., Stein & Landis, 1973). The lower counter indicated cumulative number of "errors" or point cost in one-point increments. A red light mounted directly below this counter flashed concurrently with each cost point. A series of relays, timers, and recorders located in an adjacent room served to program events and record responses. A one-way mirror between the programming and experimental rooms permitted continuous visual monitoring of the subject.

Each keypress activated a separate channel of an event recorder, with other channels recording reinforcements and light onset and offset. The third key from the subject's left (Key 3) was programmed to produce reinforcement on either a fixed-ratio 20 (FR 20), a fixed-interval 10-sec/cost (FI 10-sec/cost), or a differential reinforcement of low rates 5-sec (DRL 5) schedule of reinforcement. Responses on Keys 1, 2, and 4 comprised the collateral behavior and did not directly affect the governing of reinforcement.

Procedure

Each subject was run individually for a total of 106 min. The following instructions were read at the beginning of the session:

"On the panel in front of you are four telegraph keys, a light above each key, a points-gain counter and light, and an error counter and light. Your task is to cumulate as many points as you can on the gain counter. When you have earned 10 points, the yellow light will flash and 10 points will register on the gain counter, and when you have made an error, the red light will flash and an error will register on the error counter. Your final score is the number of gain points minus the number of errors. Your score is a measure of your ability to learn or solve problems, so try to cumulate as many gain points as you can.

"The accumulation of points or errors depends upon key-pressing. You may press a key only if the white light above that key is on. If the white light above a key is off, you may not press that key. This is the only restriction about keypressing. From time to time there may be different conditions; do not think anything is broken."

Ten subjects were randomly assigned to either the FR 20 or FI 10-sec/cost condition. During reinforcement history training, only the light directly above Key 3 was illuminated. Subjects provided with a history of FR 20 received reinforcement immediately following each 20th response. For the FI 10-sec/cost condition, responses which terminated IRTs greater than 10 sec were reinforced, while each IRT less than

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10 sec produced a point on the cumulative cost (error) counter. The cost condition was included with FI reinforcement since human subjects performing under FI schedules exhibit diverse rates and patterns of responding. The addition of response-cost has been shown to reliably produce low response rates with extended postreinforcement pauses (e.g., Weiner, 1969). After 45 min of reinforcement history training, a 1-min time-out occurred during which all lights above the keys were extinguished. Both groups then received 30 min of training on a DRL 5-sec schedule of reinforcement for responses on Key 3. During this phase, the lights above each key remained illuminated. Next, the lights above the collateral keys were turned off, indicating that these keys were not to be depressed, while responses to Key 3 continued to be reinforced on the DRL 5 schedule. After 15 min the lights above the collateral keys were turned on again, and the same conditions as during the initial acquisition phase were reinstated for 15 min.

RESULTS

During FR conditioning, subjects emitted a mean of 196.2 responses/min ($SD = 73.2$) and obtained a mean of 9.8 reinforcements/min ($SD = 3.0$). In contrast, FI subjects responded at a mean rate of 5.7 responses/min ($SD = 1.8$) and received an average of 4.8 reinforcements/min ($SD = 4.0$). The differences in response rate ($t = 9.47$, $df = 18$, $p < .001$) and reinforcement rate ($t = 4.95$, $df = 18$, $p < .001$) were statistically reliable. Inspection of the cumulative records of the last 40 min of training indicated that all FR subjects emitted high constant response rates between reinforcements without evidencing postreinforcement pauses. In marked contrast, during a comparable period FI subjects emitted a mean of only 5.6 ($SD = 2.9$) responses between successive reinforcements.

The transfer effects of these conditioning histories on DRL performance are summarized in Table 1. This shows the means and standard deviations of the percent reinforcement [(number of reinforced responses)/(total number of Key 3 responses) $\times 100$] and the number of collateral responses during the first and last 5-min intervals of DRL 5 training during the phases when the collateral keys were either present, absent, or re-presented.

Analysis of variance of the percent reinforcement

data yielded significant effects of Conditioning History [$F(1,18) = 54.39$, $p < .001$], Phases [$F(2,36) = 15.99$, $p < .001$], Intervals [$F(1,18) = 53.38$, $p < .001$], History by Phases [$F(2,36) = 12.99$, $p < .01$], History by Intervals [$F(1,18) = 9.90$, $p < .01$], and Phases by Intervals [$F(2,36) = 12.29$, $p < .01$]. Specific a priori comparisons indicated that the percent reinforcement increased from the first to the last 5-min interval preceding removal of the collateral keys for both reinforcement history groups ($ps < .001$). As shown in Table 1, the initial level of efficiency was substantially higher for the FI group than for the FR group. However, at the end of Phase 1 the efficiency of performance by the FI group remained only slightly higher and both groups exhibited an equivalent number of responses per minute.

Substantial differences between the history groups were obtained in the collateral response rates throughout Phases 1 and 3 of DRL training when the collateral keys were available. As shown in Table 1, the FR group exhibited a high rate of collateral responding (range = 151-1870) during the first 5 min of DRL training, and this rate continued to increase by the end of the initial phase. In contrast, the FI group engaged in much lower rates of collateral responding (range = 8-212) during the first 5 min of DRL training and, by the end of this phase, the collateral responding was virtually absent. For the FR group, removal of access to the collateral keys was accompanied by an abrupt decrease in the percent reinforcement ($p < .001$) and an increase in the rate of Key 3 responding ($p < .001$). Recovery in the efficiency of performance occurred during the last 5-min interval when the collateral keys were unavailable ($ps < .001$). Despite this improvement, reinstatement of the collateral keys was accompanied by a partial recovery in collateral responding and by a statistically nonsignificant increase in the percent reinforcement. In contrast, the FI group showed none of these trends. For this group, removal and subsequent reinstatement of the collateral keys was occasioned by a consistently high level of efficient DRL performance and a virtual absence of collateral responding.

Figure 1 shows the relative frequency (IRT/N) and

Table 1
Percent Reinforcement and Number of Collateral Responses During the First and Last 5-Min Intervals of DRL 5 with Collateral Keys Present (Phase 1), Absent (Phase 2), and Re-Presented (Phase 3)

Collateral Keys	FR 20 Condition History				FI 10-sec/Cost Conditioning History			
	Percent Reinforcement		Collateral Responses		Percent Reinforcement		Collateral Responses	
	M	SD	M	SD	M	SD	M	SD
Present: Phase 1								
First 5 min	19.1	19.4	653	454	51.4	29.0	108	82
Last 5 min	75.5	12.8	864	580	87.7	9.6	2	2
Absent: Phase 2								
First 5 min	11.1	28.6			90.2	5.4		
Last 5 min	50.6	38.4			91.4	8.2		
Present: Phase 3								
First 5 min	72.0	20.8	414	514	88.9	7.7	8	5
Last 5 min	80.2	13.6	376	554	90.9	7.3	2	2

Figure 1. IRT/OP and IRT/N distributions during last 5 min of FR 20 and FI 10-sec/cost conditioning, first and last 5 min of each phase during DRL 5-sec training. (Absent data points in the IRT/N distributions indicate identical values with the IRT/OP function.)

the interresponse time per opportunity to respond (IRT/OP) distributions of Key 3 responses during the last 5 min of history training and during the first and last 5 min of each phase when the DRL schedule was in effect. As shown, at the end of FR history training, subjects tended to emit relatively brief IRTs (0-2 sec) which also persisted during the initial interval of DRL training. However, by the end of Phase 1, these subjects showed clear evidence of a temporal discrimination appropriate to the DRL schedule. Removal of access to the collateral keys resulted in an abrupt shift in the IRT/N and IRT/OP distributions, revealing a disruption in temporally discriminated performance which was similar to the temporal performance evidenced at the end of FR 20 conditioning as well as during the initial 5 min of DRL training. Partial recovery of the discrimination occurred with additional exposure to the DRL schedule in the absence of the collateral keys, and complete recovery was clearly evidenced immediately following reinstatement of the collateral keys. In contrast, the FI group showed none of these effects. These subjects tended to emit relatively long IRTs (≥ 10 sec) by the end of FI training, a low probability of very brief IRTs during the initial interval of DRL training, and an accurate temporal discrimination by the end of Phase 1. For this group, removal and subsequent reinstatement of the collateral keys had no reliable effect on temporally discriminated performance.

DISCUSSION

The present results indicate that the conditioning history interacts with the DRL contingency of reinforcement to determine the manner in which humans mediate the interresponse times. More specifically, it was found that DRL performance following a history of FR conditioning was characterized by high rates of collateral behavior which regularly occurred between successively reinforced responses and that this behavior served a mediating role in maintaining temporally spaced reinforced responding. In contrast, each subject with a history of FI conditioning displayed an absence of overt collateral behavior and,

postexperimentally, these subjects reported counting the passage of time during the IRTs. Under comparable DRL training conditions, Stein and Flanagan (1974) showed that this form of covert mediation is functionally equivalent to overt collateral behavior in regulating temporally discriminated DRL performance. It is evident from these findings that a complete analysis of the transfer effects of conditioning histories on DRL performance must take into account not only the properties of the temporally spaced operant response but also the interim collateral behavior that may regularly mediate between the successively reinforced responses.

Weiner (1969) proposed that the persistence of transfer effects from previous conditioning histories is directly related to the degree that the current schedule does not make the rate of reinforcement a direct function of each response. Since a DRL schedule specifies a consistent relationship between each response and the delivery of reinforcement, the effects of different conditioning histories on DRL performance would not be expected to persist. Indeed, Weiner (1969) showed that the effects of an FR 40 history on the rate of reinforced responding during a DRL 10-sec schedule were not evident by the end of training. Similarly, in the present study, despite large initial differences between the FR 20 and FI 10-sec/cost groups in the rates to responding to the reinforced key in the IRT distributions, by the end of Phase 1 of DRL 5-sec training, the groups were equivalent on these measures. However, the persistent effects of these conditioning histories, while not reflected in the rate of the reinforced response, were evidenced in the different frequencies of collateral behavior. It is a reasonable possibility that the persistent effects of the FR conditioning history were limited to the collateral behavior component of the terminal DRL performance, since this component did not specify a direct relationship between response rate and reinforcement rate. Under these conditions, the high rate of responding during FR conditioning transferred to the collateral response keys during DRL training, and this behavior was maintained adventitiously by the reinforcement that followed IRTs of sufficient duration.

It is possible, however, that the disruption of temporally spaced DRL performance concurrent with the inaccessibility of the collateral keys exhibited by the FR group was a consequence of reinstating the stimulus conditions that were present during conditioning history training. In both conditions the lights above the collateral keys were extinguished, indicating that the keys were not to be depressed. The fact that the reinforcement contingencies that were in effect during these conditions differentially reinforced divergent response rates and

the differences in the IRT distributions of the FI group during these phases argues against this explanation.

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