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BEHAVIORAL AFTEREFFECTS OF REINFORCEMENT AND ITS OMISSION AS A FUNCTION OF REINFORCEMENT MAGNITUDE[1]

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Rats responded on a multiple fixed-interval fixed-interval schedule of reinforcement. Each complete cycle of the multiple schedule was separated from the next by a relatively long period of timeout from all schedule contingencies. A response at the end of the second component of each cycle was always reinforced with an invariant reinforcement magnitude, while reinforcement magnitude and reinforcement omission were systematically varied in the first component. Response rate in the first component was a monotonic function of reinforcement magnitude in that component. These changes in response rate in the first component did not affect response rate in the second component. When reinforcement was omitted on 50% of occasions in the first component, following reinforcement there was a reduction in response rate in the second component that was monotonically related to reinforcement magnitude. Following reinforcement omission there was an increase in response rate in the second component that was unrelated to reinforcement magnitude. When reinforcement was omitted on 100% of occasions in the first component, behavioral contrast was observed.

Performance following reinforcement omission has been studied with a variety of species in a number of different situations (*e.g.*, Amsel and Roussel, 1952; Davenport, Flaherty, and Dyrud, 1966; Gonzalez, 1970; Scull, Davies, and Amsel, 1970; Staddon and Innis, 1966; Zimmerman, 1971). Although different specific phenomena have been studied in this type of experiment, one general outcome has been universally obtained, *i.e.*, after a history of reinforcement of a given response, response rates are higher following omission of reinforcement than following reinforcement. This basic finding of the reinforcement-omission procedure has been variously labelled frustration (Scull, *et al.*, 1970), behavioral contrast (Staddon and Innis, 1966), or absence of an inhibitory effect of reinforcement (Kello, 1972; Staddon, 1967, 1970*b*). The present investigation was designed to provide data bearing on the alternative interpretations implied by these different labels through an exploration of variations in reinforcement magnitude upon response rate following reinforcement and reinforcement omission.

The effects of magnitude of reinforcement on performance following reinforcement and its omission have not been widely explored. Peckham and Amsel (1967) reported that starting and running speeds in the second alley of a double runway are faster following omission of reinforcement with discriminative stimuli in the first alley associated with eight rather than two pellets. Similarly, Wilton, Strongman, and Nerenberg (1969) reported that, for rats, rate of lever pressing following reinforcement omission increases over baseline responding as a function of increasing sucrose concentration. These studies provide reason to expect an increasing facilitation of response rate immediately following reinforcement omission as a function of increasing reinforcement magnitude.

Other evidence, including Experiment I of Peckham and Amsel (1967), provides some basis for expecting an increasing inhibition of response rate immediately following reinforcement as a function of increasing reinforcement magnitude. McHose and Gavelek (1969), for example, reported finding inhibition of per-

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formance immediately following reinforcement, and inhibition was greater following a large reinforcement magnitude than following a small one. Staddon (1970*a*) reported that response rate under a fixed-interval (FI) schedule with varied reinforcement magnitudes is inversely related to the reinforcement magnitude received in the preceding fixed interval.

The present investigation used reinforcement-omission procedures in an operant situation to assess the effect of reinforcement magnitude on performance following reinforcement and reinforcement omission. The reinforcement schedule used was similar in some respects to that employed by Staddon and Innis (1966). The schedule was basically a two-component, FI FI, multiple schedule consisting of repeated pairs of FIs, each pair separated from the next by variable periods of timeout. After stable baseline performance was attained, a reinforcement-omission condition was initiated. Under the omission condition reinforcement frequency at the end of the first FI component was reduced from 100% to 50%. In this manner, effects of reinforcement omission in the first FI component on performance in the second FI component were observed over a series of baseline-reinforcement omission-baseline sequences.

METHOD

Subjects

Four experimentally naive male Sprague-Dawley rats, approximately 100 days old at the beginning of the experiment, served. Body weight was controlled by water deprivation: sufficient water was given in the home cage to keep each rat at 75%, ± 1%, of its estimated normal-growth body weight at the beginning of each experimental session. The water given to the animals in the home cage contained 0.3 g tetracycline hydrochloride per liter of tap water. Tap water, without tetracycline, was used as the reinforcer during the experimental sessions. The estimate of normal growth was provided by a group of four equivalent rats, from the same shipment, that were maintained on a free-feeding and drinking schedule (Davenport and Goulet, 1964). Purina Lab Chow was continuously available in the home cages of both the experimental animals and the animals used to estimate the normal-growth curve.

Apparatus

A Lehigh Valley Electronics operant-conditioning chamber was equipped with a retractable lever and a 0.08-ml dipper cup. A Grason-Stadler Model 901B white-noise generator provided masking noise through a small loudspeaker inside the chamber. The chamber was enclosed within a sound-attenuating cabinet equipped with a ventilating fan and located in a temperature-controlled room. The recording of responses and all automatic scheduling of the reinforcement contingencies took place in an adjacent room.

Baseline Reinforcement Schedule

The basic reinforcement schedule used was a two-component multiple FI FI with interpolated periods of timeout from all schedule contingencies. During timeout, the chamber was not illuminated and the lever and the dipper cup were retracted from the chamber. In any given daily session the schedule consisted of 30 cycles of the two FI components, where each cycle contained the following contingencies in sequence: timeout (variable, mean = 60 sec, range = 30 to 90 sec); FI 45-sec; timeout (fixed period of 3 sec); FI 45-sec; timeout (variable, as specified above). The session schedule thus consisted of 30 repeated pairs of FIs. The FI preceding the 3-sec timeout was labelled Component 1, and the succeeding FI was labelled Component 2. The durations of timeout were selected on the basis of the report by Staddon and Innis (1966) that the immediate effects of reinforcement omission on behavior are clearly evident after a period as long as 3.2 sec, but are no longer evident after 30 sec.

At the initiation of each FI, the lever was inserted into the chamber and the stimulus associated with the particular FI component was presented. Stimuli associated with either FI component were the houselight, which flooded the chamber with diffuse illumination through the Plexiglas side wall, or two cue lights, which provided dim illumination from their specific locations mounted on the steel front wall containing the lever and the dipper cup. One stimulus was present in Component 1 and the other in Component 2; the stimuli were counterbalanced across components for the four rats. At the termination of each FI,

Table 1

Sequence of baseline and reinforcement-omission (RO) conditions, reinforcement magnitudes, and number of sessions at each condition for each rat.

		Reinforcement Magnitude in Component 1 Rat				*Number of Sessions Rat*			
Phase	*Schedule*	*S5*	*S6*	*S7*	*S8*	*S5*	*S6*	*S7*	*S8*
1	Baseline	1.50	3.00	3.00	1.50	32	26	65	32
2	RO	1.50	3.00	3.00	1.50	10	10	10	10
3	Baseline	1.50	3.00	3.00	1.50	10	10	21	10
4	Baseline	0.75	1.50	0.75	3.00	9	5	21	7
5	RO	0.75	1.50	0.75	3.00	10	10	10	10
6	Baseline	0.75	1.50	0.75	3.00	11	10	11	10
7	Baseline	1.50	3.00	3.00	1.50	12	12	13	10
8	Baseline	3.00				5			
9	Baseline	0.75				14			
10	Baseline	3.00	0.75	1.50	0.75	21	6	16	5
11	RO	3.00	0.75	1.50	0.75	10	10	10	10
12	Baseline	3.00	0.75	1.50	0.75	11	14	10	6
13	Baseline	0.75	1.50	0.75	3.00	10	11	22	10
14	Baseline	1.50	3.00	3.00	1.50	10	16	10	11
15	RO	1.50	3.00	3.00	1.50	10	10	10	10
16	Baseline	1.50	3.00	3.00	1.50	8	11	13	14
17	Baseline	3.00	0.75		0.75	11	12		10

a lever press retracted the lever and initiated reinforcement by presenting the dipper cup. Termination of reinforcement by retraction of the dipper cup extinguished the stimulus associated with the FI, and initiated the next timeout.

Experimental Design and Procedure

Experimental conditions. The sequence of experimental conditions for all rats and the numbers of sessions each rat was exposed to a given schedule are presented in Table 1. The experimental strategy interspersed assessments of the effects of reinforcement omission with observations of performance on the baseline schedule and provided for numerous systematic replications within each rat of performance previously observed. The parameter varied was magnitude of reinforcement in Component 1, which took values of 0.75, 1.50, and 3.00 sec of licking time. Duration of licking time in Component 2 was held constant at 0.75 sec.

Throughout the experiment, numbers of licks on the dipper cup were recorded. The average number of licks at the 0.75-, 1.50-, and 3.00-sec reinforcement durations was 6.7, 11.9, and 20.6, respectively. Some of the rats may have emptied the dipper cup in slightly less than the scheduled 3.00-sec reinforcement duration. However, reports that the rat drinks at a rate of about 0.03 ml per second from a drinking tube (Corbit and Luschei, 1969; Stellar and Hill, 1952), along with the lick data reported above, indicate that the reinforcement magnitude received at 3.00 sec was clearly larger than that received at 1.50 sec, and probably close to twice as large. Informal occasional visual observation suggested that the rats did not continue to lick the cup if it was emptied before the end of the 3.00-sec reinforcement duration.

Stability criteria. No rat was shifted from any baseline condition of the experiment to any other condition before its performance was judged stable. The principal criterion of stability was the rat's temporal distribution of responses within the FI, as measured by an index of curvature (Fry, Kelleher, and Cook, 1960). Responses emitted in successive 15-sec thirds of the FI were summed over the entire session and the index was calculated on the basis of these summed response counts. If all responses were emitted in the final third of the FI, the index was +0.667; if responses were distributed at a constant rate throughout the FI, the index was 0.000; if all responses were emitted in the initial third of the FI, the index was −0.667.

When baseline performance under a given magnitude of reinforcement was established for the first time, performance was judged stable if index of curvature did not vary by more than 0.100 in Component 1, nor by more than 0.060 in Component 2, for three consecutive sessions. When a given baseline performance was recovered, after having been initially established at some earlier point in time, the recovery was judged stable if index of curvature did not vary for three consecutive sessions by more than ±0.050 in Component 1, nor by more than ±0.030 in Component 2, from the mean value of the last three sessions of the former baseline. If this criterion was not met, the rat remained on the baseline schedule for a minimum of 10 sessions, until index of curvature once again did not vary by more than 0.100 in Component 1, nor by more than 0.060 in Component 2, for three consecutive sessions. In no case was a rat ever exposed to fewer than five sessions on a given schedule. In addition to these quantitative requirements, each session's cumulative record was required, by visual inspection, to reflect stable response rates.

Assessment of reinforcement omission. The effects of reinforcement omission were assessed during a number of 10-session blocks during which reinforcement was omitted in Component 1 on 50% of the cycles of the reinforcement schedule. A response at the end of Component 2 was always reinforced in both baseline and reinforcement-omission conditions. Therefore, the only difference between the two reinforcement schedules was that a response following each FI was always reinforced during a baseline condition, whereas only 50% of the responses following the Component 1 FIs were reinforced during a reinforcement-omission condition. Since the reinforcement contingency in Component 2 remained constant throughout both baseline and reinforcement-omission conditions, responding in Component 2 in the two conditions could thus be compared to assess the effects of reinforcement omission. When reinforcement was omitted, a lever press following the FI retracted the lever and, for a brief instant, presented the full dipper cup, which was immediately retracted before the rat could reach it. As in the baseline schedule, retraction of the dipper cup initiated the fixed 3-sec timeout.

The 50% reinforcement-availability schedule in Component 1 had the following characteristics: (*a*) reinforcement was always arranged for the first and the last cycle of each session; (*b*) there were no run lengths of reinforcement or reinforcement omission greater than three; (*c*) there was an equal number of transitions from reinforcement omission to reinforcement and *vice versa;* and (*d*) in each block of 10 cycles, 50% of the cycles were reinforced.

RESULTS

Summary of Performance with each FI Reinforced

For each rat, each time that stable performance was attained on a baseline schedule, mean response rate and mean index of curvature were calculated for the final three sessions over which stable performance was observed. These two mean measures represented the values of stable performance for a given subject at that particular phase of the experiment. To obtain an overall estimate for values of stable baseline performance for a given subject at a given magnitude of reinforcement, the values of stable performance at each phase with the same magnitude were averaged. For example, overall stable response rate for S5 at 0.75 sec was obtained by taking the mean of S5's stable response rate during Phases 4, 6, 9, and 13. These overall stable values for response rate and index of curvature for all subjects at all magnitudes of reinforcement are presented in Table 2.

The following general relationships are apparent in Table 2. (*a*) Response rate in Component 1 increased as magnitude of reinforcement in Component 1 increased. This relationship was monotonic for S6 and S8, and nearly so for S5 and S7. The mean differences in response rates in Component 1 were statistically reliable ($F = 6.17$, $df = 2/6$, $p < 0.05$). (*b*) There was no systematic change in response rate in Component 2 as magnitude of reinforcement in Component 1 increased ($F < 1.00$). (*c*) There was no systematic change in index of curvature in either Component 1 or Component 2 as magnitude of reinforcement in Component 1 increased (F's < 1.00). Thus, the relative distribution of responses in each FI (scalloping) was not changed in any systematic way by increases in magnitude of reinforcement in Component 1.

Table 2

Mean stable baseline response rate and index of curvature in both components of a two-component multiple FI FI schedule of reinforcement as a function of reinforcement magnitude in Component 1. Reinforcement followed every FI. Reinforcement magnitude in Component 2 was constant at 0.75 sec.

		Component 1 Reinforcement Magnitude (sec)			*Component 2 Reinforcement Magnitude (sec)*		
Measure	*Rat*	*0.75*	*1.50*	*3.00*	*0.75*	*1.50*	*3.00*
Rate (Responses per min)	S5	31.3	35.5	34.7	32.1	31.5	32.8
	S6	43.1	44.3	53.4	43.8	40.3	45.3
	S7	29.7	42.9	38.7	28.4	29.4	25.3
	S8	27.5	34.2	36.0	21.2	22.3	16.4
	Mean	32.9	39.2	40.7	31.4	30.9	30.0
Index of Curvature	S5	0.470	0.475	0.516	0.484	0.465	0.478
	S6	0.418	0.461	0.403	0.468	0.531	0.500
	S7	0.399	0.415	0.348	0.458	0.432	0.354
	S8	0.567	0.551	0.530	0.650	0.628	0.642
	Mean	0.464	0.476	0.449	0.515	0.514	0.494

Summary of Performance with Reinforcement Omission

So as not to include possible novelty effects peculiar to the first exposure to reinforcement omission, the data for the initial baseline-reinforcement omission-baseline sequence, Phases 1 to 3, were not treated in the analysis. Mean response rate and mean index of curvature were calculated for the final three sessions of each remaining 10-session reinforcement-omission condition for each subject. These two mean measures represent performance values for a given rat during a particular reinforcement-omission condition.

In order to see more easily the comparison of performance during the reinforcement-omission condition with baseline performance, each reinforcement-omission performance value was made relative to its corresponding stable baseline performance value by dividing the reinforcement-omission performance value by the corresponding baseline value. The baseline value for this purpose was taken as the mean of the stable baselines immediately preceding and following the particular reinforcement-omission condition. Thus, relative values of less than 1.00 indicate lower performance values during the reinforcement-omission condition than during the baseline condition, and relative values greater than 1.00 indicate higher performance values during the reinforcement-omission condition.

Table 3 presents relative performance values for all subjects in Component 1 and Component 2 of the reinforcement-omission conditions with responding in Component 2 separated according to whether it followed reinforcement or reinforcement omission in Component 1. The following general relationships are apparent in Table 3. (*a*) Response rate in Component 1 was uniformly lower, relative to baseline performance, during the reinforcement-omission conditions. There was no systematic change in relative response rate in Component 1, nor in index of curvature, as magnitude of reinforcement increased (F's < 1.00). (*b*) Response rate during the reinforcement-omission condition was always lower than baseline following reinforcement, and the reduction in response rate became larger as magnitude of reinforcement increased ($F = 6.11$, $df = 2/6$, $p < 0.05$). (*c*) Response rate tended to be higher than baseline following reinforcement omission, but there was no systematic relationship between this increased response rate and magnitude of reinforcement ($F < 1.00$). Rat S6 never increased response rate above its baseline, although this rat's mean response rate was always higher following reinforcement omission than following reinforcement. The general relationships in relative response rates, as reflected in mean values, are presented graphically in Figure 1. (*d*) Relative index of curvature increased following reinforcement as magnitude of re-

Table 3

Mean response rate and index of curvature, relative to a stable baseline in which reinforcement followed every FI, in both components of a two-component multiple FI FI schedule of reinforcement as a function of reinforcement magnitude. The mean performance measures in Component 2 are separated according to whether a response following the FI of Component 1 resulted in reinforcement or reinforcement omission.

					Component 2					
		Component 1			*Following Reinforcement*			*Following Reinforcement Omission*		
		Reinforcement Magnitude (sec)			*Reinforcement Magnitude (sec)*			*Reinforcement Magnitude (sec)*		
Measure	*Rat*	*0.75*	*1.50*	*3.00*	*0.75*	*1.50*	*3.00*	*0.75*	*1.50*	*3.00*
Relative Response Rate	S5	0.91	0.71	0.80	0.93	0.70	0.68	1.42	1.26	1.10
	S6	0.72	0.96	0.83	0.89	0.83	0.34	0.96	0.89	0.95
	S7	0.90	0.71	0.37	0.97	0.77	0.48	1.21	1.30	0.82
	S8	0.59	0.94	0.79	0.62	0.74	0.57	1.73	1.00	3.10
	Mean	0.78	0.83	0.70	0.85	0.76	0.52	1.33	1.11	1.49
Relative Index of Curvature	S5	0.91	1.01	0.91	0.92	1.11	1.19	0.74	0.88	1.13
	S6	1.08	1.07	1.36	1.03	1.10	1.54	0.97	1.02	1.19
	S7	0.76	0.94	1.22	1.05	0.86	1.10	0.88	0.83	1.02
	S8	1.06	0.98	0.96	0.96	0.99	1.05	0.83	0.86	0.68
	Mean	0.95	1.00	1.11	0.99	1.02	1.22	0.86	0.90	1.00

inforcement increased, although the differences between the means were only marginally reliable by conventional statistical standards ($F = 3.81$, $df = 2/6$, $p < 0.10$). This relationship was monotonic for all rats except S7. (*e*) There was no systematic change in relative index of curvature following reinforcement omission as magnitude of reinforcement increased ($F = 1.51$, $df = 2/6$).

Relations to Behavioral Contrast

Ignoring the distinction in Component 2 between occasions following reinforcement and reinforcement omission permits an assessment of the effect of reinforcement magnitude on an operation, reduction in reinforcement frequency, which usually produces behavioral contrast. If the data presented in Table 3 are viewed in this way, mean response rate for each rat in Component 2 was higher than baseline (positive behavioral contrast) generally only at 0.75 sec, where magnitude of reinforcement was the same in Components 1 and 2. The exceptions were S6, which never showed behavioral contrast, S7 which showed behavioral contrast at 1.50 sec, and S8 which showed behavioral contrast at 3.00 sec. The latter case was attributable to an unusually high selective increase in response rate following reinforcement omission (*cf.* Table 3).

Although behavioral contrast has not proved to be a phenomenon that can readily be produced by a variety of conditions (*e.g.,* Richards, 1972), the generality of the present findings would gain in credence if it could be demonstrated that the kind of reinforcement schedule used does permit contrast, as it has been studied, to occur. Therefore, a control experiment was conducted using a procedure

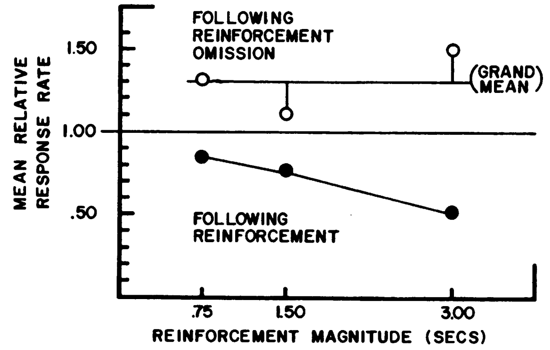

Fig. 1. Mean relative response rate in Component 2, immediately following either reinforcement or its omission in Component 1, as a function of reinforcement magnitude. (See Table 3.)

that has uniformly been reported to produce behavioral contrast, *i.e.*, the introduction of extinction into a component of a multiple schedule (Reynolds, 1961). Subjects were S5, S6, and S8. Each rat was exposed to one baseline-reinforcement omission-baseline sequence, with the same method as described above, except that during the reinforcement-omission condition a lever press following the conclusion of Component 1 always resulted in the reinforcement-omission condition of the main experiment. Technically, this procedure results in a contingency that could be referred to as a chained schedule rather than a multiple schedule; however, this procedure is also known to produce behavioral contrast in traditional paradigms (*cf.* Wilton and Gay, 1969). During the baseline conditions, which preceded and followed the 100% reinforcement-omission condition, reinforcement duration in Component 1 was 3.00 sec for S5, 0.75 sec for S6, and 1.50 sec for S8.

Mean relative response rates and index of curvature for each rat during the last three days of the reinforcement-omission condition of the control experiment are presented in Table 4. All three rats exhibited strong positive behavioral contrast, thus verifying that the reinforcement schedule used here does produce a behavioral contrast effect of the sort customarily observed in more traditional multiple schedules.

Table 4

Mean response rate and index of curvature relative to a stable baseline in which reinforcement followed every FI, in both components of an FI FI schedule. A response following the Component-1 FI always resulted in reinforcement omission.

Measure	*Rat*	*Component 1*	*Component 2*
Relative Response Rate	S5	0.20	1.58
	S6	0.32	1.70
	S8	0.36	1.23
	Mean	0.29	1.50
Relative Index of Curvature	S5	0.81	0.89
	S6	0.88	0.86
	S8	0.92	0.78
	Mean	0.87	0.84

DISCUSSION

Performance With Each FI Reinforced

There were two principal findings with respect to stable responding on the baseline schedule alone. First, increases in magnitude of reinforcement in one component of the multiple schedule produced orderly increases in response rate in that component without systematically affecting rate in the second, unchanged, component. This is a clear replication in rats of the findings reported by Shettleworth and Nevin (1965) that, for pigeons, changes in reinforcement magnitude do not consistently produce corresponding changes in the degree of behavioral contrast observed. Therefore, this finding of the present experiment strengthens the proposition that systematic changes in response rate, as a function of reinforcement magnitude at least, can be localized in one component of a multiple schedule. Second, the changes in response rate as a function of reinforcement magnitude occurred evenly across the FI, so that scalloping, as measured by index of curvature, was unaffected by changes in reinforcement magnitude. This finding is further evidence that response rate and index of curvature are independent measures of FI performance (Fry, *et al.*, 1960; Gollub, 1964).

Performance With Reinforcement Omission

There were three principal findings with respect to reinforcement omission: (*a*) reinforcement reliably acted to reduce immediately subsequent responding and this reduction increased monotonically as reinforcement magnitude increased, (*b*) the reduction in responding occurred selectively in the early portions of the FI so that scalloping, as measured by index of curvature, became more pronounced in Component 2 following reinforcement as magnitude increased, and (*c*) reinforcement omission generally increased immediately subsequent responding, but this increase was not systematically related to reinforcement magnitude. These findings are strikingly similar to those in McHose and Gavelek's (1969) report that rats in a double runway showed reduced running speed in the second alley following reinforcement, the reduction being greater with the larger of the two reinforcement magnitudes used, and showed increased running speed in the second alley following reinforcement omission, although this increase was unrelated to reinforcement magnitude. The findings are also consonant with Staddon's (1970*a*) report that an increasing reduction of response rate on an FI schedule in pigeons is a function of increasing reinforcement magnitude in the previous FI.

Because frustrative-nonreward theory (*e.g.*, Amsel, 1958, 1962; Spence, 1960, Ch. 10) clearly predicts a positive relationship between facilitation of responding following reinforcement omission and magnitude of reinforcement, there have been numerous attempts to demonstrate a relationship, most of them unsuccessful (*e.g.*, Amsel and Roussel, 1952). The exceptions have been Peckham and Amsel (1967) and Wilton, *et al.*, (1969). The Peckham and Amsel experiment has to be interpreted cautiously because of a number of methodological difficulties (discussed in detail by Staddon, 1970*b*, pp. 235-236) and therefore cannot be considered a strong demonstration. Similarly, the study by Wilton, *et al.*, found differential facilitation only at the extreme values tested, 32% *versus* 4% sucrose concentration, and then on only one of two measures analyzed. It seems prudent to conclude that whatever relationship between response facilitation following reinforcement omission and reinforcement magnitude does exist is subtle and difficult to document. The difficulty in producing an effect may well be due to the obvious fact that reinforcement magnitude is not highly salient at the moment that reinforcement is omitted, *i.e.*, it may be assumed present only through conditioned representational mediating responses.

Although discussions of "inhibitory" effects of reinforcement on second-alley performance in the double runway have occasionally appeared in the frustrative-nonreward literature (*e.g.*, Hamm, 1967; McHose, 1963; McHose and and Gavelek, 1969; Seward, Pereboom, Butler, and Jones, 1957), on the whole, frustrative-nonreward theory has taken the strong view that reinforcement omission has a facilitative effect, and has minimized or ignored the possibility that reinforcement may have an inhibitory function. Collateral evidence from several sources (*e.g.*, Terrace, 1966) has given this position a wide credibility. However, along with the results of other recent experiments using operant techniques (Platt and Senkowski, 1970; Zimmerman, 1971), the present investigation shows clearly that there is a reduction in response rate immediately following reinforcement, and further shows that this reduction is directly related to reinforcement magnitude. These data are supportive of Staddon's (*e.g.*, 1970*b*) exposition of the view that reinforcement inhibits immediately subsequent behavior.

There are obvious implications of inhibitory effects of reinforcement for the traditional measure of the "frustration effect". The frustration effect is customarily derived as a within-subjects measure by subtracting a performance value following a reinforced occasion from the corresponding value following an occasion on which reinforcement is omitted (Amsel, 1958). Clearly, if performance following reinforcement is inhibited, then a frustration effect will be obtained even if performance following reinforcement omission is not facilitated. It should be noted that in the present experiment, genuine increases in response rates were generally obtained following reinforcement omission, *i.e.*, response rate in Component 2 following reinforcement omission was higher than during corresponding baseline conditions. However, even when this was not the case, as for Rat S6, a frustration effect would still have been obtained. At least until the factors that contribute to increased response rates following reinforcement omission can be unravelled from those that contribute to decreased response rates following reinforcement, it would seem inappropriate to use difference measures such as the frustration effect as a dependent variable presumed to reflect a unitary process.

A Note Concerning Behavioral Contrast

The present results have implications for the interpretation of behavioral contrast in terms of frustrative nonreward (*e.g.*, Scull, *et al.*, 1970; Terrace, 1968, p. 738). For example, frustrative-nonreward theory predicts the occurrence of behavioral contrast when there are shifts in reinforcement magnitude that produce response-rate changes. Yet the baseline schedule of the present investigation produced response-rate changes in Component 1 as a function of reinforcement magnitude without producing behavioral contrast. Furthermore, in the reinforcement-omission condition it is clear from Table 3 that behavioral contrast was limited exclusively to those occasions following reinforcement omission. Therefore, it is not possible to account for the average behavioral contrast of a given rat without also emphasizing the role of "inhibition" by reinforcement upon immediately subsequent responding. It appears from Table 3 that average behavioral contrast was more likely at the 0.75-sec magnitude than at the 1.50-sec or 3.00-sec magnitudes because inhibition of responding by reinforcement was least at the 0.75-sec magnitude.

Conclusion

This investigation has shown that, in a reinforcement-omission situation, response rate is reduced by immediately preceding reinforcement in direct relation to the magnitude of the reinforcement, and that response rate is increased by immediately preceding reinforcement omission, although this increase is not apparently related to reinforcement magnitude. These data bear chiefly upon two theoretical systems, one facilitative (Amsel, 1958), and the other inhibitory (Staddon, 1970b). Of the two, the data may be encompassed by the inhibitory theory, but cannot be readily explained by the facilitative approach without tortuous *post-hoc* assumptions. Thus, Staddon's (1970*b*) account of reinforcement-omission phenomena in terms of the discriminative after-effects of reinforcement appears at present to be the single most persuasive integrative framework.

We do not wish to rule out the possibility that two processes are operative in reinforcement-omission situations, although such a formulation is unparsimonious and perhaps premature at this stage. Nonetheless, there are, for example, suggestions that inhibitory effects of reinforcement and facilitative effects of reinforcement omission respond to different independent variables. Thus, inhibition is responsive to reinforcement magnitude, while facilitation is not. Similarly, it appears that inhibition is dependent upon some form of prior experience (Platt and Senkowski, 1970), while facilitation is not (Wagner, 1959). It is likely that other variables, such as time since the event of reinforcement or its omission (Scobie and Fallon, 1972), will also differentiate the effects.

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