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REINFORCEMENT OMISSION ON TEMPORAL GO–NO-GO SCHEDULES[1]

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Either a partial blackout, or the blackout plus a "feeder flash", occurred in lieu of reinforcement on two procedures that produced opposite patterns of responding after reinforcement. Response rate was elevated after reinforcement omission on the procedure that produced a "pause-and-respond" pattern following reinforcement, but depressed after reinforcement omission on the procedure that produced a "respond-and-pause" pattern. The effect of blackout plus feeder flash was generally intermediate between the effects of blackout and the effects of reinforcement. These results are consistent with an interpretation of reinforcement omission effects in terms of the discriminative temporal control exerted by reinforcement and stimuli similar to it.

Reinforcement schedules may be classified according to the pattern of responding following each reinforcement that they typically produce. Thus, fixed-interval (FI) and fixed-ratio (FR) schedules produce a pause followed (either abruptly or gradually) by responding (pause and respond pattern), variable-interval (VI) schedules usually produce a steady rate of responding that varies little as a function of postreinforcement time, and Staddon (1970*b*) has described a schedule in which response rate is high just after reinforcement and decreases thereafter (respond-and-pause pattern).

There is a simple relationship between the postreinforcement pattern of responding on a given schedule and the effects of omitting occasional reinforcements on that schedule: given a pause-and-respond pattern, for example, response rate after an event occurring in lieu of reinforcement is generally higher than after reinforcement (Staddon and Innis, 1969; McMillan, 1971; Zimmerman, 1971); conversely, given a respond-and-pause pattern following reinforcement, responding following reinforcement omission is generally depressed by comparison with responding after reinforcement (Staddon, 1970*b*). If postreinforcement responding varies little with time, as on many variable-interval schedules, the effects of reinforcement omission are small (McMillan, 1971).

This relationship between the effects of reinforcement omission and the temporal pattern of postreinforcement responding has been explained in terms of the temporal discriminative control exerted by reinforcement and the events associated with it (Staddon and Innis, 1969; Staddon, 1970*b*). The present paper extends the domain of this relationship by showing that the procedure earlier used to produce a respond-and-pause pattern can also be used to produce a pause-and-respond (*i.e.*, "FI-like") pattern, and that the effect of reinforcement omission in this case is similar to the effect of reinforcement omission on FI. The experiment also explored the effects of varying the similarity between the event occurring in lieu of reinforcement and the stimulus complex associated with reinforcement.

METHOD

Subjects

Four male White Carneaux pigeons, with previous experimental experience, were maintained at 80% of their free-feeding weights.

Apparatus

An aluminum and Plexiglas chamber, 11.5 by 9.75 by 9.75 in. (29 by 26 by 26 cm) (internal dimensions), enclosed in a larger soundproofed box, was used. A Gerbrands translucent pigeon key and grain feeder were mounted on one

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aluminum wall. The key was not illuminated. General illumination was provided by two 15-w fluorescent lights mounted over the chamber, parallel to the magazine wall. The light closer to the magazine wall went off during reinforcement (2.5-sec access to the illuminated food magazine). A TV camera and videotape recorder allowed undetected monitoring of the pigeons' behavior. Scheduling was accomplished by means of the usual timers and associated switching circuitry, located in another room. White noise and a ventilating fan provided masking noise. Peck data were recorded on cumulative, event, and digital recorders.

Procedure

The experiment involved training pairs of subjects on one of two baseline schedules until performance stabilized, followed by two separate reinforcement-omission test sessions that were separated by several baseline sessions. After the second test, the pairs were switched to the other baseline schedule, and, after behavior had once again stabilized, were tested a third time.

On both baseline schedules, reinforcement availability was scheduled by a VI 60-sec tape loop that ran continuously between reinforcements. The tape halted both during reinforcement and when a reinforcement was available but the required response had not yet occurred. The type of response required depended upon postreinforcement time. On the temporal "go—no-go" (G-NG) procedure, key pecking was the required response for the first 60 sec of postreinforcement time; at the 60-sec point, a 10-sec recycling timer, reset by key pecks, became operative and the reinforcer was delivered by the variable-interval tape, providing this timer had timed out. Thus, the reinforced response at postreinforcement times greater than 60 sec was not-pecking for 10 sec or more (DRO 10-sec contingency). No external stimulus change was correlated with the change in contingencies. Reinforcements were distributed irregularly on the variable-interval tape, with the restriction that half the interreinforcement intervals were longer and half shorter than 60 sec in length, with a mean of 60 sec. The temporal "no-go—go" (NG-G) procedure was the reverse of the G-NG, with the 10-sec recycling timer operative for the first 60 sec of postreinforcement time, and key pecking the required response thereafter.

The sequence of conditions and the number of sessions spent in each is shown in Table 1.

Omission Tests

All the pigeons received a total of three test sessions when the effect of presenting a stimulus in lieu of reinforcement was assessed. The stimulus (N: nonreinforcement) was turning off (for 2.5 sec) the fluorescent light that was normally turned off during the operation of the food magazine. This event was scheduled in exactly the same way as reinforcement; *i.e.*, it occurred for pecking at postreinforcement times shorter than 60 sec (on the G-NG schedule) or longer than 60 sec (on the NG-G schedule), and for not pecking at other times. Reinforcements and nonreinforcements were scheduled by a special tape that had alternate intervals either 60 sec in length ("FI 60" in Figure 1) or of variable length ("VI x" in Figure 1). The 60-sec intervals always ended in reinforcement. There were eight variable-duration intervals: 5, 10, 30, 50, 70, 80, 90, and 110 sec in length. Half of these intervals are longer and half shorter than 60 sec, so that the event occurring at the end of the interval, reinforcement or nonreinforcement, occurred equally often for pecking or not pecking. Each of the variable-duration intervals occurred six times during each test and half ended in reinforcement, half in nonreinforcement. This

Table 1

Sequence of conditions and number of sessions (in parentheses) for the four pigeons. Details of NG-G and G-NG schedules and tests are described in text. For the first three sessions of the first Baseline condition the DRO value was 5 rather than 10 sec.

Bird	*Baseline*	*Test 1*	*Baseline*	*Test 2*	*Baseline*	*Test 3*
67	G-NG (32)	(1)	G-NG (6)	(1)	NG-G (25)	(1)
41	G-NG (33)	(1)	G-NG (6)	(1)	NG-G (25)	(1)
33	NG-G (33)	(1)	NG-G (6)	(1)	G-NG (25)	(1)
30	NG-G (32)	(1)	NG-G (6)	(1)	G-NG (25)	(1)

procedure was in force for the first two omission tests for each bird (Figure 1, top).

Test 3 was similar to Tests 1 and 2, except that during half the non-reinforcements the food magazine was briefly operated (FF: feeder flash) for about 0.7 sec, a duration too short to allow the birds to obtain food. This procedure is shown at the bottom of Figure 1.

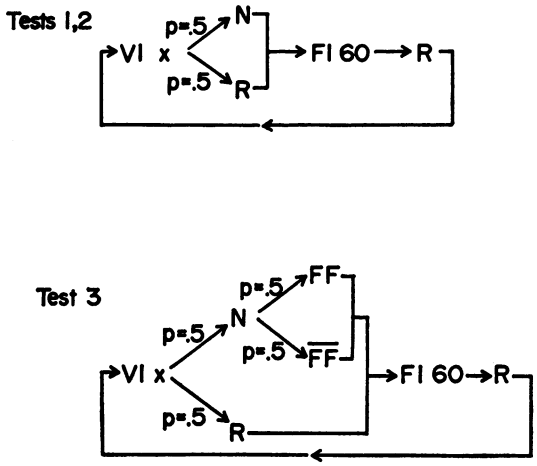

Fig. 1. Scheduling of interreinforcement intervals, reinforcement (R), nonreinforcement (N), feeder flash (FF) and no feeder flash ($\overline{FF}$), during reinforcement omission test sessions. Temporal contingency (G-NG or NG-G) was in force throughout, with the required response (pecking or not pecking) changing at the 60-sec postreinforcement time.

RESULTS

Baseline Schedule

Figure 2 shows cumulative records of stable performances obtained from the four pigeons under both the no-go–go (NG-G) schedule, and the opposite go–no-go (G-NG) schedule. The NG-G schedule produced a "pause-and-respond" pattern after each reinforcement, which resembles typical fixed-interval behavior. The cumulative records look like fixed-interval records, save for the variation in interreinforcement interval. The G-NG schedule produces the opposite "respond-and-pause" pattern after each reinforcement.

Although both procedures were effective in controlling responding, there were small differences between them in the time of the transition after reinforcement between pecking and not pecking. Table 2 shows average time from reinforcement to the first interresponse time shorter than 10 sec (10 sec was the DRO requirement for the not-responding phase of each schedule) on the NG-G procedure, and time to the last interresponse time (IRT) shorter than 10 sec on the G-NG procedure. In both cases, the times are measured from the end of reinforcement to the key peck initiating the criterion IRT. The values are averages of one session's stable responding. The switch, either from pecking to not pecking, or the reverse, occurred early on both schedules (*i.e.*, before the 60-sec postreinforcement time), but in the case of the G-NG schedule this was true only for the time to the last IRT shorter than 10 sec: over-all time to the *last response* within each interreinforcement interval was 72.7 sec, as opposed to the 41.1 sec in Table 2. For the NG-G schedule, on the other hand, average time to the *first response* within each interval

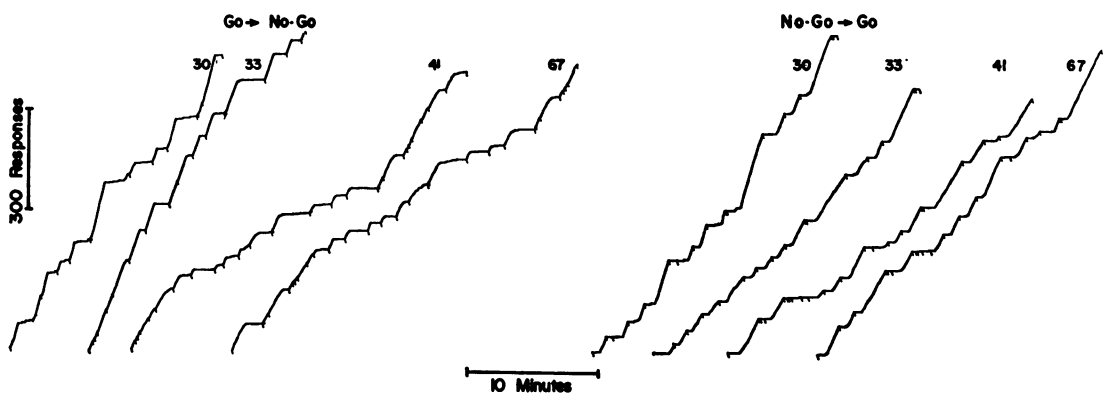

Fig. 2. Cumulative records of stable performances under the two schedules for the four pigeons. On the go–no-go schedule, pecking was reinforced for the first 60 sec of postreinforcement time, and not pecking, for 10 sec or more, thereafter. On the no-go–go schedule, these contingencies were reversed. Diagonal blips indicate reinforcement.

was essentially the same as the time given in Table 2.

Most pigeons developed a recognizable pattern of behavior as a function of postreinforcement time on both the G-NG and NG-G procedures. Figure 3 summarizes the behavior of one pigeon on the G-NG schedule, as recorded by an observer from a 30-min videotape record. The figure shows the relative frequency of each of five activities in each successive 5-sec block of postreinforcement time. This particular bird had two well-marked activities: key pecking, which occurred in the period just after reinforcement, and pacing against the back wall, facing away from the key at longer postreinforcement times. All the birds typically faced the back wall, away from the key, during the not-pecking period on the G-NG schedule, and turned to one side (not to the back wall) during not-pecking periods on the NG-G schedule. The pacing activity in Figure 3 was shown clearly by one bird, and intermittently by one other, during not-pecking periods on both schedules; the other birds showed bowing and head-bobbing movements during these periods.

Table 2

Time to first (NG-G) or last (G-NG) < 10-sec IRT within each interreinforcement interval (seconds).

Bird	*NG-G (first IRT)*	*G-NG (last IRT)*
33	17.3	46.4
30	25.3	44.6
67	27.5	31.4
41	35.0	41.9
Mean	26.3	41.1

Omission Tests

The individual results for the three reinforcement omission tests appear as Table 3.

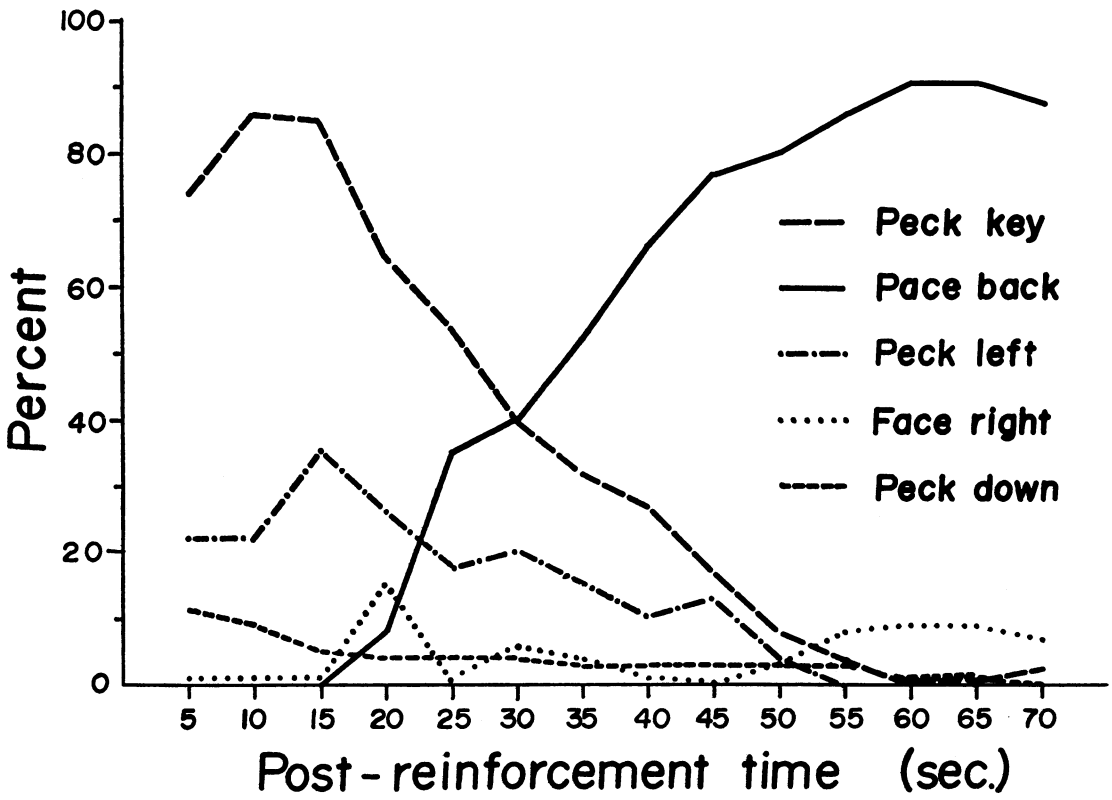

Fig. 3. Behaviors shown by Pigeon 67 as a function of postreinforcement time on the go—no-go schedule. The ordinate shows the percentage of interreinforcement intervals when a given activity occurred in each second of postreinforcement time, averaged across 5-sec blocks. The figure shows five behaviors: peck key, pecking movements directed at the response key; Pace back, side-to-side pacing with breastbone pressed against the back wall of the box; Peck left, pecking movements directed to the left of the response key; Face right, facing the wall to the right of the key; Peck down, pecking movements directed downward.

Table 3

Postreinforcement time

		Postreinforcement time (Required response)					
		0-60 sec (Not pecking)			*>60 sec (Pecking)*		
	Bird	*N*	*FF*	*R*	*N*	*FF*	*R*
NG-G ('pause and respond')	33 (1)	80.4	—	37.4	81.9	—	49.5
	(2)	65.0	—	34.9	71.8	—	36.2
	30 (1)	69.2	—	53.3	70.6	—	45.3
	(2)	78.3	—	54.3	68.8	—	55.0
	Mean	73.2	—	45.0	73.3	—	46.5
	67 (3)	65.5	72.1	30.4	78.3	67.3	31.8
	41 (3)	47.6	33.1	22.1	43.5	40.0	22.7

		(Pecking)			*(Not pecking)*		
	Bird	*N*	*FF*	*R*	*N*	*FF*	*R*
G-NG ('respond and pause')	67 (1)	13.2	—	34.9	6.18	—	30.5
	(2)	6.92	—	34.3	6.43	—	33.8
	41 (1)	7.09	—	38.1	2.75	—	30.1
	(2)	4.75	—	35.8	2.92	—	25.4
	Mean	7.99	—	35.8	4.57	—	30.0
	33 (3)	9.0	7.63	78.4	1.50	2.63	38.3
	30 (3)	11.0	24.1	87.2	9.88	29.9	50.3

Responses in the 60-sec period following either reinforcement (R), nonreinforcement (N—dimming of general illumination) or nonreinforcement with a "feeder flash" (FF), on the two procedures. Numbers in parentheses give the number of the test in question for each bird. Left half of table gives data following interreinforcement intervals shorter than 60 sec in duration; the right half for intervals longer than 60 sec.

Three points can be made about these results:

(1) The effects of reinforcement omission depend upon the baseline schedule: under the NG-G procedure (which produces "FI-like" behavior, see Figure 2) responding was greater following reinforcement omission (N) than following reinforcement (R). Under the G-NG procedure, on the other hand, responding was much less following N than following R. These differences were independent of whether N or R occurred for pecking or not pecking. They can be most easily seen in the mean data for Tests 1 and 2, but are also shown by all the individual pigeons.

(2) With two small exceptions in eight generalization tests (Bird 67, NG-G; Bird 33, G-NG), responding following reinforcement omission with feeder flash was intermediate between responding following reinforcement omission without feeder flash and responding was intermediate following reinforcement.

(3) There is an asymmetry between the effects of the G-NG and NG-G procedures. It can be most easily seen in Table 4, which is a condensation of Table 3. It shows the overall average rate following N or R on the two procedures as a function of the postreinforcement time at which the event occurred, either longer or shorter than 60 sec. From the table it can be seen that for the G-NG procedure, rate following both R and N was lower if either of these two events occurred at postreinforcement times longer than 60 sec (*i.e.*, for not pecking) than if they occurred at shorter times (*i.e.*, for pecking). No such difference is apparent under the NG-G procedure.

DISCUSSION

Response rate following a stimulus presented in lieu of reinforcement (*i.e.*, nonreinforcement) on schedules that produce a pause-

Table 4

Over-all mean data, taken from Table 3, showing responses per minute following reinforcement or nonreinforcement, as a function of the postreinforcement time at which these two events occurred (either longer or shorter than 60 sec) on the go—no-go and no-go—go procedures.

		Procedure			
		G-NG		*NG-G*	
	Following:	*N*	*R*	*N*	*R*
Postreinforcement	0-60	8.66	51.4	67.7	38.7
Time (sec)	>60	4.94	34.7	69.2	40.1

and-respond pattern following reinforcement (*e.g.*, FI, FR) is higher than response rate following reinforcement on those schedules (the omission or "frustration" effect: Scull, Davies, and Amsel, 1970; Staddon and Innis, 1969; McMillan, 1971). Response rate following nonreinforcement on a schedule that produces a respond-and-pause pattern following reinforcement has recently been shown to be lower than the rate following reinforcement on that schedule (Staddon, 1970*b*). The results of reinforcement omission on the G-NG (respond-and-pause) schedule in the present experiment replicate the earlier data; the results of reinforcement omission on the NG-G (pause-and-respond) schedule show that these data do not reflect a peculiarity of the DRO contingency used to suppress pecking on the G-NG schedule, since the effect of nonreinforcement may easily be reversed. The reinforcement omission results on these two schedules and others can be subsumed under the empirical generalization that the effects of reinforcement omission on a given procedure depend upon the temporal pattern of responding that typically follows (*i.e.*, is controlled by) reinforcement on that procedure: if the pattern is pause-and-respond ("FI-like"), reinforcement omission elevates responding; if it is respond-and-pause (*e.g.*, the G-NG schedule), reinforcement omission depresses responding, by comparison with responding following reinforcement.

The relationship between postreinforcement pattern of responding and the effects of reinforcement omission may be explained in terms of the temporal discriminative control exerted by reinforcement and stimuli similar to it. Thus, on fixed-interval schedules, responding is depressed following reinforcement and increases thereafter; reinforcement may therefore be said to exert inhibitory temporal control over subsequent responding. Conversely, on the G-NG (respond-and-pause) schedule, reinforcement exerts excitatory temporal control over key pecking. In each case, a stimulus presented in lieu of reinforcement is likely, via generalization decrement, to exert a similar, though weaker, effect, so that response rate following nonreinforcement on FI will be less inhibited, and therefore higher, than responding following reinforcement (and conversely for the G-NG schedule). The results of reinforcement omission tests with a "feeder flash" tend to confirm this analysis, since in six of eight cases, response rate following reinforcement omission with the feeder flash was intermediate between responding following reinforcement and response rate following reinforcement omission without the feeder flash, *i.e.*, responding in each case was related in the expected way to the similarity to reinforcement of the stimulus presented in lieu of reinforcement.

This result has been confirmed and extended in an experiment by Kello (1972) who found, after FI 2-min training, that response rate following blackout (Blkt) reinforcement (R), blackout plus food-magazine light (ML), and complete reinforcement omission with no stimulus presented in lieu (0) was in the order of the similarity of these events to reinforcement, *i.e.*, 0 > Blkt > ML > R.

On the G-NG procedure, if reinforcement or nonreinforcement occurred while the birds were not pecking (*i.e.*, more than 60 sec after reinforcement), the rate following these events was lower than if they occurred while they were pecking. No comparable asymmetry was observed on the NG-G procedure (see Table 4). This difference may be related to the different behaviors developed by the birds during the not-pecking periods on these two schedules: On the G-NG schedule, the pigeons typically turned completely away from the magazine wall and the light whose offset signalled both reinforcement and nonreinforcement. On the NG-G procedure, on the other hand, the turning away was only partial and the animals usually faced the side wall. This difference may have introduced some delay between the occurrence of reinforcement or nonreinforcement as objective events and their reception by the animal during the not-pecking periods on the G-NG schedule. Since it has elsewhere been shown that reduction in the duration of

either reinforcement or nonreinforcement tends to reduce their effects (Staddon and Innis, 1969; Staddon, 1970*a*), such a delay might be responsible for the smaller effects of both reinforcement and nonreinforcement when they occurred during not-pecking periods on the G-NG schedule.

The pigeons on the NG-G schedule began to peck earlier, after each reinforcement, than they ceased to peck on the G-NG schedule. This difference between the birds' adaptation to the two procedures might suggest a bias in favor of pecking as opposed to the activity engaged in during the not-pecking periods, since the birds start to peck early (on the NG-G schedule) and stop pecking late (on the G-NG schedule). This is a possible interpretation, but there is also an asymmetry in the procedures that has two effects, either of which might underly this apparent bias. First, because of the 10-sec not-pecking requirement, the earliest that reinforcement could occur under this contingency on the G-NG schedule was 70 sec (60 + 10) after reinforcement, whereas on the NG-G schedule, the first peck-produced reinforcement could occur approximately 60 sec after reinforcement. Given this difference, the birds on NG-G might well start to peck sooner after reinforcement than they cease pecking on G-NG. Second, while pecks are reinforced with no delay on both procedures (because there is a real contingency for pecking), "not pecking" is unspecified, so that the behavior that falls into this category will not be as closely or as reliably followed by reinforcement as is pecking. In terms of the notion of reinforcement as *selection* (Staddon, 1972), there is selection for pecking, during the pecking periods, and against pecking but not for any other behavior during the not-pecking periods on both schedules. This asymmetry may have been sufficient to delay the offset, and advance the onset, of pecking relative to not pecking on both schedules. Replication of the present experiment, with a specific response other than pecking (*e.g.*, "pacing") being reinforced during the not-pecking period, will be necessary to decide whether the apparent bias seen here reflects a property of pecking or a bias in the contingencies of reinforcement.

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