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REINFORCEMENT OMISSION ON FIXED-INTERVAL SCHEDULES[1]

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Experiments with pigeons and rats showed that: (1) When a brief blackout was presented in lieu of reinforcement at the end of 25% of intervals on a fixed-interval 2-min schedule, response rate was reliably and persistently higher during the following 2-min intervals (omission effect). This effect was largely due to a decrease in time to first response after reinforcement omission. (2) When blackout duration was varied, within sessions, over the range 2 to 32 sec, time to first response was inversely related to the duration of the preceding blackout, for pigeons, and for rats during the first few sessions after the transition from FI 2-min to FI 2-min with reinforcement omission. Post-blackout pause was independent of blackout duration for rats at asymptote. These results were interpreted in terms of differential depressive effects of reinforcement and blackout on subsequent responding.

CONTENTS

Hungry animals will quickly learn to obtain food that is available at a fixed point in space (*e.g.*, the mid-goal box of a double runway) or time (*e.g.*, fixed-interval schedules). Moreover, the effects of reinforcement omission are similar in both cases: an increased running speed, in the second runway of the double runway apparatus (the frustration effect, Amsel and Roussel, 1952), and a higher overall rate of responding following nonreinforcement on fixed-interval schedules (Staddon and Innis, 1966). The runway effect has usually been interpreted in motivational terms (frustrative nonreward, Amsel, 1958), while the interval schedule effect has been described in terms of discriminative effects of reinforcement (Staddon, 1967).

The following experiments examined the effect of three factors on the elevation in response rate that follows reinforcement omission on fixed-interval schedules. The first experiment demonstrated the effect with rats, and attempted to replicate some effects of stimuli found in the previous pigeon experiment (Staddon and Innis, 1966). The second experiment examined the effect of varying the duration of the blackout associated with both reinforcement and nonreinforcement (timeout or TO).

EXPERIMENT 1: EFFECT OF DIFFERENTIAL STIMULI

In a previous experiment (Staddon and Innis, 1966), pigeons were exposed to a sequence of 2-min fixed intervals (80 per session). The first, third, *etc.* intervals of each session ended either with (response-contingent) reinforcement or brief blackout (TO), of the same duration as reinforcement, with equal probability (50% intervals). Consequently, the second, fourth, *etc.* intervals began either with reinforcement or TO, but always ended with reinforcement (100% intervals). Since reinforcement always occurred with house and key lights out, there are similarities between reinforcement and TO, in addition to their duration and their identical temporal relationship to preceding and following reinforcements. The main outcome of this experiment was the consistently higher response rate in intervals that began with TO, compared to intervals that began with reinforcement. By analogy with the frustration effect of Amsel, this effect will be termed the *omission effect.*

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In the previous experiment, differential stimuli (red *vs.* green keylights) were sometimes associated with the 50% and 100% intervals. Under these conditions, three of the four pigeons responded slightly more slowly during the 50% intervals than during comparable 100% intervals. The first part of this experiment was an attempt to replicate this effect of the differential stimuli associated with 50% and 100% intervals.

The second part of this experiment was an attempt to show the omission effect with rats. Later conditions of the rat experiment also attempted to show an effect of differential stimuli. Although both rats and pigeons showed the omission effect, no clear effect of the differential stimuli was demonstrated.

METHOD

Subjects

Experiment 1A. Four male White Carneaux pigeons were used, two experimentally naive (32, 33), and two from the previous reinforcement omission experiment (227, 435). The birds were maintained throughout at 80% of their free-feeding weights.

Experiment 1B. Four experimentally naive male hooded rats, maintained at 80% of their free-feeding weight at the beginning of the experiment, were used.

Apparatus

The pigeons' experimental chamber was a wire cage of about 16-in. cube enclosed in a larger soundproofed box. One wall of the cage was a Masonite panel on which was mounted a Gerbrands pigeon key and grain dispenser. The key could be transilluminated by different-colored Christmas tree bulbs. Effective key pecks (a force of about 18 g was required) produced an audible "feedback" click. The magazine aperture was illuminated during reinforcement (3.2-sec access to mixed grain) and the house and key lights were turned off.

For the rats, the experimental chamber was a one-lever box for rats (R. Gerbrands Co.) enclosed in a large soundproofed box. Effective lever presses (a force of about 40 g was required) produced an audible click from a relay mounted behind the response panel. During reinforcement (3.2-sec access to a dipper of 50% water and 50% Eagle Brand sweetened condensed milk in complete darkness) and timeout, lever presses produced no auditory feedback. Lever presses were recorded separately during houselight-on and houselight-off periods.

Noise from the ventilating fan masked most extraneous sounds in both experiments. In addition, white noise was present for the pigeon experiment. Recording and automatic scheduling equipment was located in an adjoining room. Responses were recorded on digital and printout counters, and a cumulative recorder.

Procedure

Two basic procedures were used: fixed-interval 2-min (FI 2-min), and fixed-interval 2-min with reinforcement omission (FI omission). Sessions under both procedures involved 80 fixed intervals. One cycle of the FI-omission procedure appears in Fig. 1A. A cycle comprised two 2-min intervals; the first ended either with a response-contingent TO of 3.2 sec duration (nonreinforcement), or with reinforcement, with equal probability (50% intervals). The sequence of reinforcements (R) and TOs (N) in the 50% intervals during the FI-

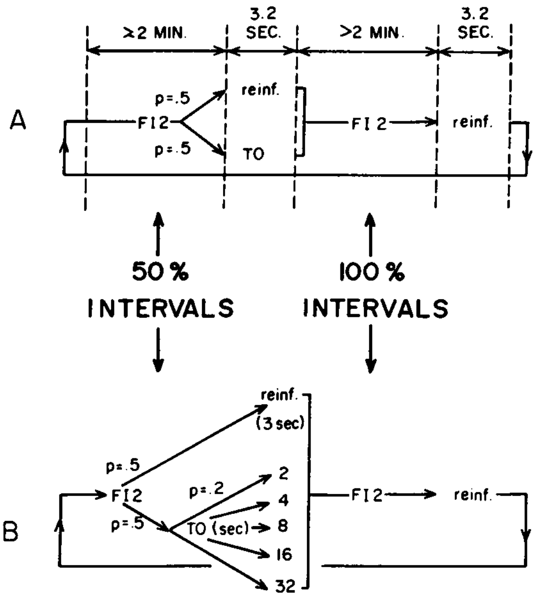

Fig. 1. One cycle of the FI-omission procedures used in Exp. 1 (top panel) and Exp. 2 (bottom panel). In both cases a cycle involved two 2-min intervals, one invariably ending in food reinforcement (100% intervals) and one ending in food or blackout (TO) with equal probability (50% intervals). For the first procedure, TO was always 3.2 sec (the duration of reinforcement), for the second, one of five TO durations occurred with equal probability (FI omission, asymmetric).

omission condition was determined by the repeating sequence NNNRRNRRNR . . . (four repeats per session). The second interval of the cycle (100% intervals) always ended with reinforcement. During the FI 2-min condition, data from alternate intervals were recorded separately for comparative purposes. Sessions began and ended in the dark. During the initial conditions of both experiments, the same stimulus (houselight—rats; houselight and white key—pigeons) was associated with both 50% intervals and 100% intervals; during later conditions, differential stimuli were associated with 50% and 100% intervals respectively. Animals were run daily in this and all the following experiments.

Experiment 1A (pigeons). After magazine and key-peck training, the two naive birds were given a session of about 30 reinforcements on FR 1, followed by 30 on VI 1-min. All four pigeons were then given 10 sessions of FI 2, with white keylight, followed by seven sessions of FI omission with red and green keylights (counterbalanced among the four birds) differentially associated with 50% and 100% intervals. The FI 2-min condition, with white keylight, was then reinstated and was followed by a number of alternations of FI omission and FI 2-min, with and without differential stimuli. A total of four FI-omission conditions with differential stimuli, and five without were given. Each condition involved at least four sessions and averaged six. With the exception of the last three FI-omission conditions (without, with, and without differential stimuli), successive FI-omission conditions were separated by at least six FI 2-min sessions. The last condition of the experiment was 11 sessions of a mixed schedule involving 20 cycles per session of an FI 4, FI 2, FI 2-min cycle.

Experiment 1B (rats). After magazine and lever-press training, the rats received about 50 reinforcements on FR 1. They then received 13 sessions of FI 2-min followed by 14 sessions of FI omission followed by seven sessions of FI 2-min with different stimuli (white noise and 1000-Hz tone) associated with alternate fixed intervals. A number of FI-omission and FI 2-min conditions then followed, with and without differential stimuli (tone *vs.* noise, tone *vs.* silence, or bright direct lighting *vs.* dim indirect lighting, usually counterbalanced among the animals) associated with 50% and 100% intervals respectively. The stimuli were sometimes reversed in significance during test sessions or alternately presented in extinction sessions. The rats' behavior with the differential stimuli differed little from their behavior without the stimuli, and therefore the differential conditions will not be discussed in detail.

RESULTS

The results of the pigeon experiment are summarized in Table 1, which shows the overall mean rate of responding, for all sessions of FI omission, with and without differential stimuli in 50% and 100% intervals. The main outcome was the much higher overall rate of responding in 100% intervals that began with TO [100% (N)] by comparison

Table 1

Mean response rates (per minute) during fixed intervals that always ended with reinforcement (100% intervals) or ended with reinforcement half the time (50% intervals). Response rate during 100% intervals that began with reinforcement [100% (R)] or timeout [100% (N)] appears in separate columns and the two halves of the table show response rates with (four conditions) and without (five conditions) differential stimuli associated with 50% and 100% intervals respectively. "P/" columns give the number (out of four or five) of conditions showing a 50% *vs.* 100% (R) difference in the same direction as the mean difference for that bird. Data are averaged across all sessions of each condition for each bird.

	Differential Stimuli				*No Differential Stimuli*			
Bird	*50%*	*100% (R)*	*P/4*	*100% (N)*	*50%*	*100% (R)*	*P/5*	*100% (N)*
435	10.4	8.2	4	19.2	9.9	11.0	4	24.2
32	45.5	46.9	3	53.5	52.5	53.0	2	62.8
33	45.0	41.5	3	48.9	40.8	44.3	5	66.0
227	22.0	25.2	3	34.3	16.7	19.2	4	26.5
Mean	30.7	30.5		39.0	30.0	31.9		44.9

with the intervals that began with reinforcement [100% (R)].

The reinforcement rate associated with the 50% intervals was only half that associated with the 100% intervals, since the former ended with reinforcement only half the time. When differential stimuli were associated with the 50% and 100% intervals, and considering only those intervals that began with reinforcement, three out of four pigeons in the previous experiment responded faster during 100% intervals than during 50% intervals. Under similar conditions in this experiment, only Bird 435 showed a consistent difference, which was in the opposite direction to the previous finding [50% > 100% (R)]. Moreover, in the nondifferential conditions, Birds 435 and 33 showed consistent, though small, differences favoring 100% (R). In the absence of any external stimulus cues, these differences are probably attributable to differences in the sequences of reinforced and nonreinforced intervals preceding 50% intervals, and 100% intervals beginning with reinforcement. Taking the group as a whole there is no evidence for a consistent difference in response rate between 50% intervals and 100% intervals that began with reinforcement, with or without differential stimuli.

The overall response rate in the 100% intervals beginning with reinforcement [100% (R)] or TO [100% (N)], as well as response rate during the 50% intervals, is shown in Fig. 2 for the first three conditions of both rat and pigeon experiments. The points are averages of four animals in both cases, but the means

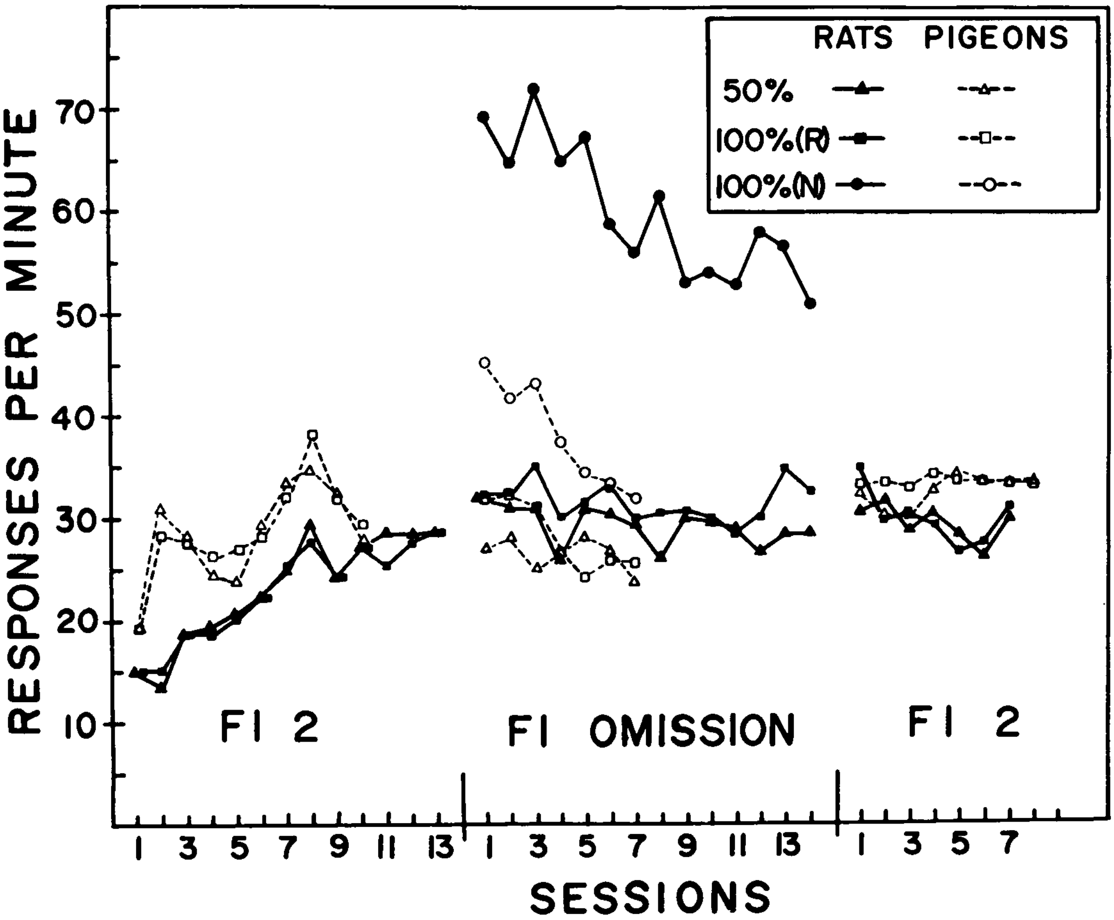

Fig. 2. Daily group average response rates in 50% intervals (50%) and 100% intervals beginning with reinforcement [100% (R)], or timeout [100% (N)], for rats and pigeons during the first three conditions of Exp. 1A and B. "FI OMISSION" in the procedure of Fig. 1A; the 50% and 100% (R) curves during the FI 2-min conditions simply denote response rate in alternate fixed intervals for comparison purposes.

are representative of the individual data. All four rats responded faster after TO than after reinforcement (omission effect). Three out of four rats (and all four pigeons) showed the decline in omission effect shown by the average. In the various repetitions of FI omission, with and without differential stimuli, the decline in the omission effect over sessions seen in Fig. 2 was the commonest pattern observed, although occasionally some animals (both rats and pigeons) showed no change or even some increase in the effect over sessions. Overall response rates in 50% intervals and 100% intervals that began with reinforcement were closely similar for all the rats; as with the pigeons there was no evidence of any consistent effect of the stimuli over the group as a whole. The rats consistently showed a larger omission effect than the pigeons throughout this experiment, as indicated in the figure. Inspection of cumulative records indicated that this difference is traceable to shorter post-TO pauses rather than to longer average postreinforcement pauses by the rats.

Figure 3 shows cumulative records for Rat G-2 for seven cycles of the first session of the FI-omission condition of the previous figure. The upper record represents the pecking of a similarly trained pigeon under the same conditions. The two records are similar and they indicate that the elevation in responding after nonreinforcement depicted in the previous figure represents a shortening of the post-TO pause, *i.e.*, "running through" in the sense of Ferster and Skinner (1957), rather than an increase in the "running" response rate. Both rats and pigeons simply started to respond sooner after TO. This point is amplified in the second experiment.

The blackout and lack of auditory feedback during TO achieved good control over the responding of both rats and pigeons; neither rats nor pigeons responded significantly during TOs.

There is an obvious analogy between the FI-omission procedure of Fig. 1A and a mixed FI 4, FI 2-min schedule with FI 2-min and FI 4-min occurring in the ratio 2:1. Thus, a 50% interval ending in TO and followed by a 100% interval is analogous to FI 4-min (except for the single response required after 2 min, and assuming the intervening TO has no effect), while either a 50% interval ending with reinforcement or a 100% interval beginning (and ending) with reinforcement is simply FI 2-min. Using this analogy it is possible to compute (from printing counter records) the overall response rate during the "FI 2-min" intervals [*i.e.*, 50%, 100% (R)] and "FI 4-min" intervals (*i.e.*, the combined average rate in 50% intervals ending in TO and 100% intervals beginning with TO) for both the FI-omission procedure of Fig. 1A and the cyclic mixed schedule (FI 4 FI 2 FI 2-min) that was the last condition of this experiment. These data are shown, for each pigeon and for the average, for the last three days of the last FI-omission condition and the first and last three days of the mixed cyclic FI (MIX 1 and 2) in Table 2. There was little difference between the "FI 2-min" response rates under the two procedures, but the "FI 4-min" rates (an in-

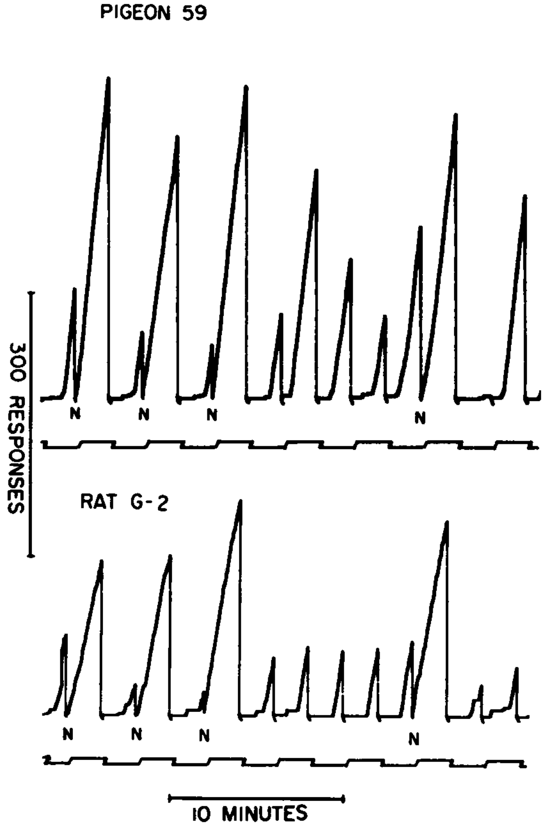

Fig. 3. Sample cumulative records from the first day of the first FI-omission condition of Exp. 1B (rat) and a comparable record from a similarly trained pigeon (Staddon and Innis, 1966). The response pen reset at the end of each interval. "N" denotes intervals ending in 3.2-sec blackouts in lieu of reinforcement. The event pen indicates 50% intervals (pen depressed) and 100% intervals.

Table 2

Mean response rate (per minute) for the four pigeons during the "FI 2-min" and "FI 4-min" interreinforcement intervals for the last three days of the FI-omission condition (Fig. 1A) and the first (MIX 1) and last (MIX 2) three days of the MIX FI 4 FI 2 FI 2 condition. See text for details.

	"FI 2"			*"FI 4"*		
Bird	*FI Omission*	*MIX 1*	*MIX 2*	*FI Omission*	*MIX 1*	*MIX 2*
435	9.3	6.0	7.3	12.9	15.6	14.9
32	67.1	69.4	69.8	69.3	78.1	86.6
33	40.6	44.8	47.8	47.3	64.6	73.8
227	17.1	19.2	16.5	21.6	40.7	29.8
Mean	33.5	34.9	35.4	37.8	49.8	51.3

dex of the omission effect) were in every case greater under the mixed schedule. Thus, by comparison with a mixed schedule with the same distribution of interreinforcement intervals, the introduction of TO reduces response rate over the following interval. A similar result was obtained, with another group of pigeons, using a mixed schedule in which the FI 4 and FI 2-min components occurred in an irregular sequence (rather than cyclically) based upon the sequence used to schedule nonreinforced TOs in the FI-omission conditions of this experiment.

EXPERIMENT 2: EFFECT OF BLACKOUT DURATION

The previous experiment showed that presenting a brief TO in lieu of reinforcement on FI 2-min increased the number of key pecks emitted during the next interval. Rate over the following interval was still further increased when reinforcement was omitted entirely and no stimulus presented in its stead (mixed schedule). Since the omission effect is a measure of the difference between the response rate after reinforcement and after the stimulus presented in lieu of reinforcement, this result indicates a bigger omission effect due to the presentation of no stimulus than due to the presentation of TO. A plausible inference from these results is that the omission effect is in fact inversely proportional to TO duration: the longer the TO presented in lieu of reinforcement, the lower the rate of responding over the subsequent interval, and thus the smaller the omission effect. The present experiment investigated this possibility by presenting TOs of various durations during each experimental session. The expected inverse relationship was found for pigeons, and for rats early in training.

METHOD

Subjects

Eight male White Carneaux pigeons, two experimentally naive (35, 40), two with experience on interval schedule reinforcement omission experiments (227, 437), and four with experience on spaced responding schedules, and eight male hooded rats, two from the previous experiment (R-1, G-2) and six experimentally naive, were used.

Apparatus

For both pigeons and rats, the apparatus was the same as in the previous experiment. White noise and the noise of the ventilating fan masked most extraneous sounds in both the rat and pigeon experiments. Reinforcement duration was 3 sec. Scheduling was by relays and an optical film reader (C. H. Stoelting Co.) located in an adjoining room.

Procedure

There were three procedures: FI 2-min, FI omission, asymmetric (asym); and FI omission, symmetric (sym). FI omission, asymmetric, is depicted in Fig. 1B. It involved the same basic procedure as the FI omission of the previous experiment, except that TO (blackout) duration was not the same on each presentation; five durations, over the range 2 to 32 sec, occurred with equal frequency. The five durations were in geometric progression to minimize the possibility of a temporal discrimination based on blackout duration; they were scheduled according to an irregular sequence. FI omission, symmetric, was similar to the asymmetric condition, except that the blackouts of different durations were associated with the termination of all 50% intervals, reinforced and nonreinforced. Blackout duration was timed from the onset of reinforcement and thus the shortest blackout associated with reinforcement was 3 sec, rather than 2 sec. For the symmetric condition, the following reinforcement/nonreinforcement sequence, and associated sequence of blackout durations, was used (Blkt. duration in sec):

Reinf.:	R	N	N	R	R	N	R	N	N	N	R	R
Blkt.:	16	8	2	4	32	4	2	32	16	16	8	2
Reinf.:	N	R	R	R	N	R	R	N	N	R	N	N
Blkt.:	32	32	8	4	2	16	4	8	4	16	4	16
Reinf.:	R	N	R	R	N	N						
Blkt.:	2	8	32	8	32	2						

For the asymmetric condition of Fig. 1B only the nonreinforcement part of this sequence was used. A session involved two cycles of this sequence in both cases. Sessions comprised 60 intervals. Naive animals usually received one session of 60 reinforcements on FR 1 before the start of an experiment.

The two pigeon and two rat experimental groups and the number of sessions under each condition appear in Table 3. Two of the birds in group Pigeon-1 were given 14 sessions of FI-2 min before exposure to FI omission, the other two were on FI omission from the start. Since the FI-omission data for these four birds were similar, they will be considered as one group for all the FI-omission conditions (Conditions 2, 3, and 4).

RESULTS

The results of the FI-omission conditions for the four groups are summarized in Fig. 4. The data are five-day averages, across four animals, taken from the latter part of the conditions. The curves are in every case quite representative of the data for individual animals. All four FI-omission conditions using pigeons (three for Pigeon-1, one for Pigeon-2, left panel) showed substantially the same results: (a) overall response rate after nonreinforcement (TO) was substantially higher than response rate after reinforcement for most TO durations; (b) response rate was inversely related to the duration of the antecedent TO—the longer the TO the lower the subsequent rate; (c) there was little effect of blackout duration on subsequent responding when reinforcement began the blackout, although all four pigeons in this condition (FI omission, symmetric) showed the slight tendency to respond faster after the 16- and 32-sec blackouts indicated by the average curve; three of these four birds responded fastest after 16-sec blackout and two of the three responded slightly faster after the reinforced 16-sec blackouts than following 16 sec TOs.

These data show some tendency for overall response rate to rise slightly after the two longest (16 and 32 sec) TO durations. This effect is shown by three of the four pigeon FI-omission replications in Fig. 4, as well as by the function for reinforced blackouts (sym-reinf). On the other hand, the effect was not apparent during early sessions of the first FI-omission condition for group Pigeon-1 (Condition 2) and did not occur for group Pigeon-2.

Table 3

Subjects, sequence of conditions and number of sessions under each condition for the four groups. "Asym" is the FI-omission, asymmetric condition shown in Fig. 1B; "sym", the FI-omission, symmetric condition was similar except that blackouts followed both reinforced and nonreinforced fixed intervals (see text).

	Group								
	Pigeon-1			*Pigeon-2*		*Rat-1*		*Rat-2*	
Subjects	*40, 227,*	*35, 437*	*Sessions*	*4 Pigeons*	*Sessions*	*B-1, B-2 R-1, G-2*	*Sessions*	*4 Rats*	*Sessions*
Condition									
1	FI 2	asym	14	FI 2	14	FI 2	14	asym	18
2	asym		25	asym	16	asym	31	–	–
3	sym		27	–	–	–	–	–	–
4	asym		18	–	–	–	–	–	–

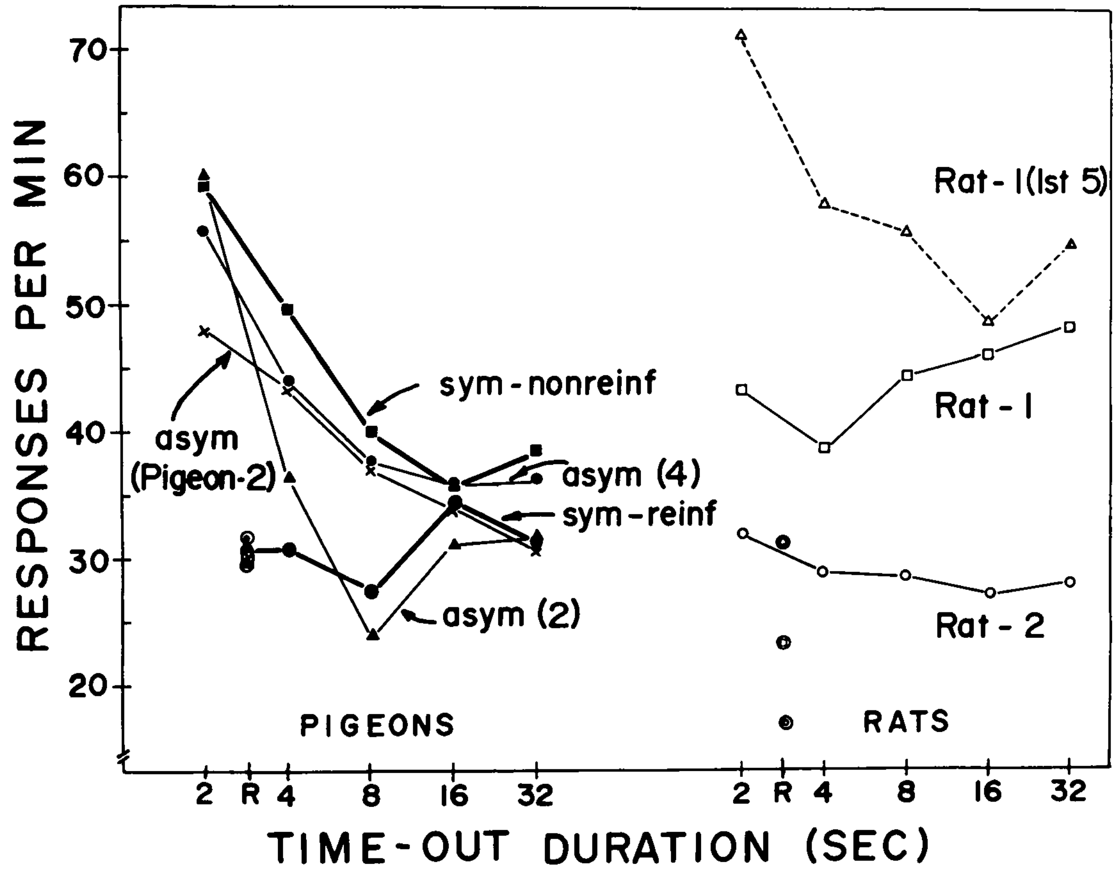

Fig. 4. Response rate in 2-min fixed intervals either after 3-sec reinforcements (points above "R" on the abscissa), after TOs of various durations ("asym" and "sym-nonreinf") or after blackouts of various durations with reinforcement occurring at the beginning of each ("sym-reinf"). All points are averages across five days and four animals per group for all the FI-omission conditions of Exp. 2. "Asym" is the asymmetric procedure shown in Fig. 1B, "sym" is similar except that variable-duration blackouts were presented at the end of both reinforced and nonreinforced intervals (symmetric procedure, see text). Left panel (pigeons): Crosses are data for group Pigeon-2, asymmetric condition, other curves are for group Pigeon-1 for the indicated conditions (see Table 3). Right panel (rats): Data for the asymmetric conditions for the two groups. Dashed line is data from the first five days of the asymmetric condition for group Rat-1.

The results of the FI-omission, asymmetric conditions of the two rat experiments appear in the right-hand panel of Fig. 4. The data for the last five days of the two asymmetric conditions agree with the pigeon results in showing a higher overall response rate after nonreinforcement (TO) than after reinforcement, although the magnitude of the effect is larger for the rats and there was an effect after all TO durations. These results differ from the pigeon data in showing little effect of TO duration; in group Rat-1, two rats (B-1, G-2) showed slightly declining functions, the others (R-1, B-2) showed functions that increased slightly between the 16- and 32-sec TO values. In group Rat-2, all four rats showed flat functions. The large difference in mean rate between curves for groups Rat-1 and Rat-2 is due to the inclusion of one rat with a very high rate in the first group and one with a low rate in the second.

The dashed function in the right-hand panel of Fig. 4 indicates that the discrepancy between the rat and pigeon data just alluded to reflects a difference in the effects of practice: the data for the first five days of the FI-omission condition for group Rat-1 (which received pretraining on FI 2-min) are similar to the pigeon data in most respects; *i.e.*, lower rates after longer TOs, together with some tendency for the rate to rise after the longest TOs. A difference, however, is that all the rats showed a higher rate after TO than after reinforcement (omission effect) even after the longest TO, whereas the pigeons showed a negligible effect after the 32-sec TOs. Examination of individual data showed that this differential effect of TO duration disappeared within 10 sessions for all rats, whereas it was maintained relatively permanently by the pigeons. It was not shown at all by any of the four rats that experienced only FI omission (group Rat-2).

Figure 5, which shows average data from the last five days of FI omission, asymmetric for group Pigeon-2 and group Rat-2, indicates that most of the effect of TO duration on overall rate shown by the pigeons is via the postreinforcement (post-TO) pause. Pauses were much longer after the longer TOs; and the pause after 32-sec TOs almost equaled that after reinforcement. The effect of the TO duration on "running" rate (*i.e.*, response rate over the period from the first response of an interval until reinforcement) was much less, being largely restricted to a slightly higher rate after the shortest (2-sec) TO for two of the four birds.

With the sole difference that TO duration had no systematic effect on post-TO pause, the rat data were quite similar to the pigeon results. Running rate was much the same after reinforcement and nonreinforcement and most of the omission effect was due to shorter pauses after TO.

In neither the rat nor the pigeon experiments was there any clear difference, at asymptote, between the animals run throughout under FI omission and the animals run first on FI 2-min and then on FI omission.

A possible interpretation of the monotonically increasing TO duration *vs.* post-TO pause function shown by the pigeons in Fig. 5

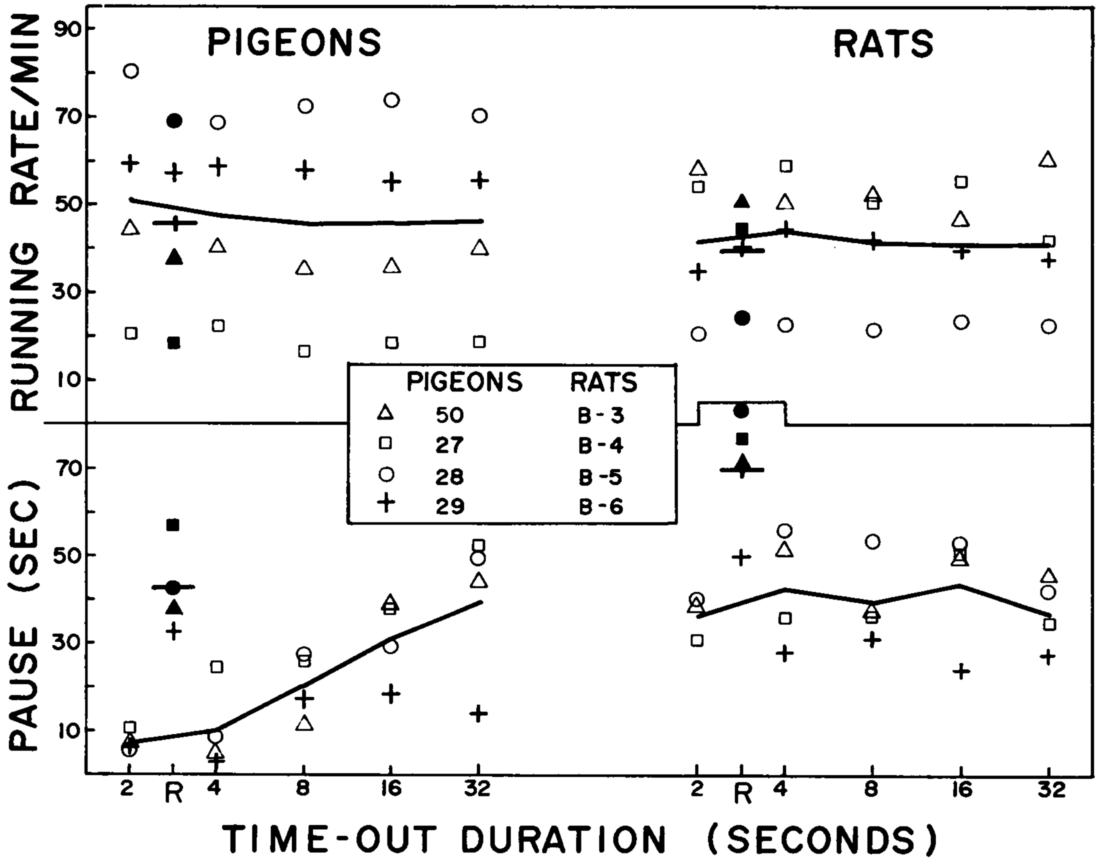

Fig. 5. Pause and "running" rate (response rate after the first response of an interval) following reinforcement (filled symbols between 2 and 4 sec) and TO for the FI-omission, asymmetric conditions for groups Pigeon-2 and Rat-2 in Exp. 2. Points are five-day averages of steady-state responding for each animal and lines are drawn through the means of these. Horizontal bars between 2 and 4 sec ("R" on the abscissa) are the overall means after reinforcement.

is that it is due to a mixture of the two kinds of responding shown in Exp. 1; *i.e.*, a mixture of short pauses, such as those that typically followed TOs, and long pauses such as those that followed reinforcement. The function of Fig. 5 might have resulted from an effect of TO duration on the relative frequency of these two patterns. The distribution of pauses for each interval following each TO value was computed over the five-day period of Fig. 5 for each pigeon. In no case, however, did these distributions show any evidence of the bimodality implied by this interpretation. Distributions were usually unimodal, with the modes close to the mean values of Fig. 5, and there were few very short pauses.

GENERAL DISCUSSION

Both experiments showed that on a fixed-interval 2-min schedule, presentation of a brief TO in lieu of reinforcement increased the number of responses made during the following 2-min interval. Further, this increase in rate was due almost entirely to a decrease in the time-to-first-response after TO as compared to time-to-first-response after reinforcement. In the second experiment, the pause after TO was shown to be inversely related to the duration of the TO, for pigeons, with the pause after the longest TOs (32 sec) approximately the same as after reinforcement. For the rats trained initially on FI 2-min before exposure to the reinforcement omission procedure, this relationship was true only for the first few sessions under FI omission. There was no effect of TO duration on subsequent responding for those rats trained throughout on FI omission.

For the pigeons, TO evidently had inhibitory after-effects (temporal inhibition), both because pigeons in the first experiment responded more slowly when TO was presented in lieu of reinforcement than when nothing was presented (*i.e.*, the last 2 min of FI 4-min in the mixed schedule) and because post-TO pause increased following longer TOs in the second experiment. There is no reason to avoid a similar conclusion for the rats, although the evidence is less complete. Three factors may contribute to the temporal inhibitory effect of TO: (1) TOs were always presented with a fixed temporal relationship to the next reinforcement. In this respect these experiments resemble studies on the effects of stimuli interpolated during fixed-interval (*e.g.*, Farmer and Schoenfeld, 1966 *a*, *b*). Comparable data from Farmer and Schoenfeld (1966*b*) tend to confirm this view, showing fewer responses during the 24 sec following a 6-sec stimulus interpolated 30 sec after the preceding reinforcement on FI 60-sec than during the same period under simple FI. (2) The TO here can be considered as a stimulus resembling reinforcement, since reinforcement occurred with houselight and keylight off. If reinforcement on FI depresses responding after its offset, TO may be expected (*via* generalization) to acquire similar, though weaker, temporal inhibitory properties. (3) Although synchronous presentation of reinforcement and a neutral stimulus is relatively ineffective in producing conditioned reinforcement, the pairing of blackout and food here may be a factor in the acquisition of temporal inhibitory properties by TO. Thus, Farmer and Schoenfeld (1966*b*) showed that responding during the second half of a 60-sec fixed interval is lower when an added stimulus is presented both in the middle and at the end of the interval than when it is presented only in the middle. Similarly, de Lorge (1967) and Stubbs (1969) showed that contiguity between an added stimulus and reinforcement enhances "scalloping" following the added stimulus on second-order FI.

The necessary and sufficient conditions for the acquisition of some temporal inhibitory control by TO are not defined by these experiments. The similarity between TO and reinforcement is probably important, and the fixed temporal relationship between these two events may play some role as FI omission training progresses. Additional experiments are necessary both to explore this issue and to clarify the different effects of TO duration with rats and pigeons.

In summary, the present results are consistent with an interpretation of the omission effect in terms of selective control of pausing by reinforcement and, to a lesser extent, by TO presented in lieu of reinforcement. The difference between these two temporal inhibitory effects appears as an elevation in responding (decrease in pause) after TO, by comparison with responding after reinforcement. This rate difference is the omission effect. This conclusion confirms and extends our previous interpretation of interval schedule "frustration" effects, and of some effects of cyclic interval schedules, in terms of selective temporal inhibition of responding by reinforcement (Staddon, 1967; Innis and Staddon, 1969).

Frustrative Nonreward

These experiments have obvious analogies to the double-runway frustrative nonreward experiments of Amsel (1958) and others. In addition, a number of free-operant experiments analogous to the double-runway have been reported where the essential identity between effects obtained in the double-runway and in lever-pressing apparatus has been assumed (*e.g.*, Davenport and Thompson, 1965; Davenport, Flaherty, and Dyrud, 1966). While direct comparison between these two classes of situation is difficult, both because of the procedural differences between them and because of the different theoretical traditions within which the work has been carried out, comparison of results, at least, should still prove fruitful. In this respect, the similarities are perhaps more striking than the differences. In both the runway experiments and the experiments reported here, "starting time" is shorter after nonreinforcement than after reinforcement (*cf.* Amsel and Roussel, 1952; Wagner, 1959), and the effect is relatively stable over sessions (or trials) (*cf.* McHose, 1963). A third similarity is the rapid onset of the omission effect (frustration effect) after the transition from FI 2-min (continuous in Amsel's terminology) to FI omission (partial): in all our experiments, the effect was maximal during the first FI-omission session and Amsel and Roussel report the appearance of the effect within the first few partial trials. A fourth point is the tendency for the effect to be higher at short detention times (TO durations) than long (Exp. 2 here; MacKinnon and Amsel, 1964; Davenport, Flaherty, and Dyrud, 1966). A final point is the emergence of an omission effect with or without initial training under a continuous condition (*cf.* Wagner, 1959).

On grounds of parsimony, therefore, it is risky to assume different mechanisms for these two effects. According to Amsel "frustration", as it relates to nonreward, is a " . . . conceptualization of a hypothetical, implicit reaction elicited by nonreward after a number of prior rewards" (1958, p. 103). And ". . . frustrative-nonreward events determine activating (drive) effects, which can be measured as an increase in the vigor of behavior which immediately follows the frustrative events . . ." (*ibid*, p. 103). Further, a frustrative event is defined as ". . . the absence of or delay of a rewarding event in a situation where it had been present previously" (*ibid*, p. 102).

In terms of these definitions, animals should evidently be more frustrated after the onset of a response-contingent TO, at a post-reinforcement time of 2 min (after FI 2-min training), than if no TO had occurred, since TO comes closer to being a "situation where [reward] had been present previously" than the 2-min postreinforcement time in the presence of an illuminated key, houselight, *etc.* Yet the results of the mixed schedule control condition in Exp. 1 (and numerous other experiments in our laboratory) clearly indicate that response rate after "no event" is reliably higher than after a brief TO, after fixed-interval training (this was one justification for attributing mild inhibitory after-effects to TO). It is hard to see how frustrative nonreward theory can aid in understanding this difference.

The results of the second experiment are also to some extent inconsistent with frustrative nonreward theory, which suggests that ". . . the greatest FE [frustration effect] should appear following some intermediate time of detention . . . on nonreward trials . . ." (MacKinnon and Amsel, 1964, p. 473). In the present experiment, response rate (and thus the omission/frustration effect) was inversely related to the preceding TO duration (analogous to "detention time"), with no suggestion of a maximum at any intermediate value.

Since there is a simple alternative explanation for the results of these experiments, there is little reason to adopt a frustrative nonreward analysis here. To the extent that fixed-interval and runway situations are similar, these results cast doubts on motivational interpretations of the "frustration" effect in favor of an explanation in terms of purely discriminative effects of reinforcement and stimuli occurring in lieu of reinforcement.

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