THE BEHAVIORAL EFFECTS OF REPEATED EXPOSURE TO THREE MIXED EXTINCTION SCHEDULES

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Ferster and Skinner (1957), using pigeons, mention a mixed fixed-ratio extinction schedule. After a varying number of consecutive fixed ratios, a long period of time was presented, unmarked by external stimulus changes, during which all reinforcement was withheld. This period was followed by a brief time out, during which responding was suppressed, and then by the reinstatement of the usual stimulus conditions along with another series of fixed ratios followed by extinction. Many sessions under this program led to normal fixed-ratio performance when that component schedule was in effect. With the advent of extinction, no concurrent S^{Δ} being presented, birds came to emit a "priming" run as if on FR. After considerable training, the birds' extinction responding stopped shortly after they had completed the usual fixed-ratio requirement. Although additional runs with ratio-like rates were often emitted in extinction after the stoppage, the remainder of each extinction period was for the most part characterized by a total absence of responding.

Such a program may be termed "trained extinction." Despite repeated exposure to extinction conditions, the subject continues to have available only the cues emanating from the absence of reinforcement to rely upon in order to discriminate the no-reinforcement condition. Continued trials enable the resulting extinction behavior to stabilize and be evaluated in the steady state.

The nature of a single extinction session after fixed-ratio (FR), fixed-interval (FI), and differential reinforcement of low rate (DRL) schedules has also been demonstrated. An FR usually gives an extinction curve which oscillates between the high rates of ratio behavior and zero or very low rates (Skinner, 1938; Ferster & Skinner, 1957). Little responding at intermediate rates is evident. Short fixed intervals, on the other hand, tend to result in smoothly decelerating extinction curves, where the terminal FI rate gradually decreases to zero levels (Ferster & Skinner, 1957, p. 473). It is known that DRL also results in gradually negatively accelerated extinction curves containing, in the words of Wilson and Keller (1953), "none of the emotional bursts found in extinction curves following regular reinforcement."

It is of interest to determine and compare the nature of trained stabilized extinction after these three common reinforcement schedules, FR, FI, and DRL; and for this purpose, appropriate mixed extinction programs may be established. The ease with which subjects can respond appropriately to extinction, with a particular one of these three reinforcement contingencies in operation outside of extinction, is an indication of the extent to which subjects can respond to cues derived from the number of responses they emit (FR), the amount of time which elapses (FI), or the emission of particular inter-response times (DRL).

METHOD

Subjects

Subjects were six male albino rats, received at 90 days and maintained in the laboratory for some 20 days before experimental procedures were begun. Rats F-19, F-20,

and F-21 were not previously run under any schedule other than the ratio procedure to be described. Rats E-9, E-10, and E-11, on the other hand, were exposed to two separate procedures, stability being examined on each one. Various drugs were administered to these three rats before they were shifted from their first procedure, but such treatments were suspended more than 3 months prior to obtaining data from their second procedure. All rats were maintained at 80% of their 90-day-old weight throughout the experiments.

Apparatus

Rats worked in a commercially produced Skinner Box (Foringer & Co., Inc., Rockville, Md.). The important parts in the present experiment were a lever with a clicking relay attached for purposes of giving auditory feedback after each lever-pressing response; a motor-driven dipper which could present diluted-milk reinforcement to subjects, and a 7.5-watt stimulus light located over the lever. The various reinforcement and stimulus contingencies were programmed into the box via electromechanical relay circuitry.

Procedure

Stable extinction responding collected after more than 3 months' exposure to each of three reinforcement conditions was examined. Disregarding the exact nature of the reinforcement programs for the present, each session was composed of various segments, as follows: Two reinforcements could first be obtained by the subject by responding appropriately to the existing reinforcement component. Then, with no immediate stimulus change, 10 minutes of extinction was programmed. The last 30 seconds of this period consisted of a light-on condition with no programmed reinforcement. Responses during this time reset the 30-second clock and thus forestalled by 30 seconds the termination of this light-on period. Such responses were recorded with signal marks on the cumulative curves to be presented. When 30 seconds of light-on did elapse with no responses emitted, the light went off, thus returning the subject to the usual light-off stimulus condition. This light contingency served to signal the return of the reinforcement component. In addition, the no-response requirement eliminated many responses which a pilot study had shown were often emitted towards the end of extinction, probably being maintained through spurious reinforcement. After this first extinction unit, consisting of a total of at least 10 minutes, nine reinforcements were programmed, followed by a second extinction unit; six reinforcements were then programmed, and a third extinction unit followed. The sequence of two reinforcements—extinction—nine reinforcements—extinction—six reinforcements—extinction was repeated two more times, the session terminating just after the ninth extinction period of the day; thus, a total of 51 reinforcements was received during each session.

For Rats F-17, F-18, and F-19, the reinforcement component consisted of a fixed ratio of 24:1; initial work, however, had begun with this ratio equal to 48:1 for a few sessions.

Rats E-9, E-10, and E-11 were placed on a fixed interval of 2 minutes, as their first reinforcement contingency. Later, after stability on this program had been achieved and investigated, these subjects were switched to DRL 20 seconds as their reinforcement component.

Each rat was placed in the box for its daily session only if its pre-experimental weight was not more than the 80% figure previously determined. Upon completion of the session, the rat was again weighed, and was rationed enough lab chow to return its body weight to the 80% level.

RESULTS

Mix FR 25 ext

Figure 1 illustrates typical stable performance on mix FR 24 ext. Ratio segments consist of consistently rapid rates; the slight discrepancies in the height of the individual ratios in Fig. 1 were the result of the subject's frequent overshoots (continued responding just

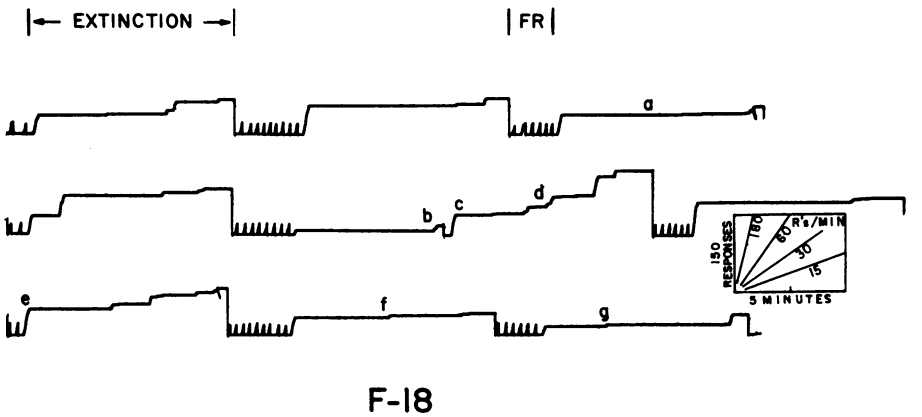

Figure 1. Typical behavior under mix FR 24 ext 10 minutes.

after the dipper rose). One notably irregular ratio appeared at *b*; responding stopped after about ten responses, and was not resumed for some 8 minutes, whereupon the ratio was completed. The other portions of the curve covering large areas consisted of the nine interspersed extinction periods. These retained the squared look described by Ferster and Skinner (1957), although examples of intermediate rates in the midst of extinction (e.g., *d*) and negatively accelerated priming runs (*c* and *e*) were observed. The sample record includes no extinction periods during which responding was totally absent following the priming run, although such instances were not rare. A few extinctions, as at *a* and *f*, contain no more than a handful of responses after the initial run. At the end of the "a" extinction period, a single response during the light-on period occurred, indicated by the signal mark just before the end of that extinction period.

The extinction at *g* contained an initial priming run even shorter than the fixed ratio which applied. This occurrence arose only occasionally; during the session pictured, such a shortened run occurred twice, the other time being at the ratio at *b*. (Rats had no means, of course, of discriminations between extinction and FR until 24 responses were emitted.) Careful checking of the equipment invariable revealed that no exteroceptive cues were available to subjects throughout extinction, except for the terminal light-on condition.

Table 1 presents the averaged data from the last 10 stability days from the three subjects under each schedule. On the average, for the mixed-ratio schedule, somewhat more than 24 responses were emitted per reinforcement, reflecting the frequent overshooting on ratios. During each extinction period, a mean of from 2.6 (Rat F-18) to 5.3 (Rat F-19) extinction responses was emitted for each response per reinforcement during the ratio phase. The standard deviations in Table 1 were calculated on the basis of the 10 daily sessions, how-

Table 1
Stable Response Measures from Three Mixed Extinction Schedules

Schedule	Total Extinction R's		R's in S^R Component		*Total Extinction R's*[b] R's in S^R Component	
			S^R's[a]		S^R's	
	M	SD	M	SD	M	SD
Mix FR24 ext 10′						
Rat F-17	735.6	182.8	24.4	0.3	3.3	1.2
Rat F-18	561.3	144.5	24.1	0.7	2.6	0.6
Rat F-19	1223.4	218.4	25.8	0.4	5.3	0.9
Mix FI2′ ext 10′						
Rat E-9	1293.2	140.6	51.1	5.6	2.8	0.2
Rat E-10	1103.6	156.6	39.5	8.5	3.2	0.4
Rat E-11	1376.9	419.9	48.1	21.6	3.2	0.9
Mix DRL20″ ext 10′						
Rat E-9	181.6	53.4	2.0	0.4	10.0	2.6
Rat E-10	132.8	28.7	2.0	0.6	8.0	1.9
Rat E-11	102.2	21.9	1.5	0.2	7.5	1.3

Note.— All means and SD's are calculated from total scores on each of ten consecutive sessions on each schedule after apparent stability was reached.

[a]The number of S^R's in each session was fixed at 51.

[b]This measure represents the mean number of extinction responses in each extinction period of the session in relation to the mean responses per reinforcement in that session.

ever, and would probably be much larger if calculated for each extinction period. The index described indicates to what extent the subjects were able to curtail responding during extinction; as the ratio approaches 1.0, it indicates that a subject is more and more efficient in responding appropriately to the mixed extinction. Thus, a rat on CRF would score 1.0 if during extinction it regularly makes only a single (unreinforced) response and subsequently fails to respond. Figure 1 indicates that individual extinction periods contributed very unevenly to this index.

The index for Rat F-19 was higher than that for the other two rats on this schedule, reflecting an atypical performance in comparison with F-17, F-18, and Ferster and Skinner's birds. Figure 2 illustrates this subject's behavior, and is representative of many months of daily exposure to mix FR 24 ext. Plateaus of no responding usually followed the initial priming runs in extinction. Thereafter, however, a ragged series of short bursts and pauses was sustained, with only occasional responses in the light-on phase of extinction. For the most part, F-19's extinction responding was positively accelerated up until the onset of the light-on period.

Mix FI 2 minutes ext

Figure 3 presents a typical day's performance of Rat E-9, and resembles the other records from E-9, E-10, and E-11 on the mix FI ext schedule.

Most of the fixed-interval curves consisted of pauses for more than half of the 2 minutes comprising each interval, followed by an immediate or at least rapid transition into a high

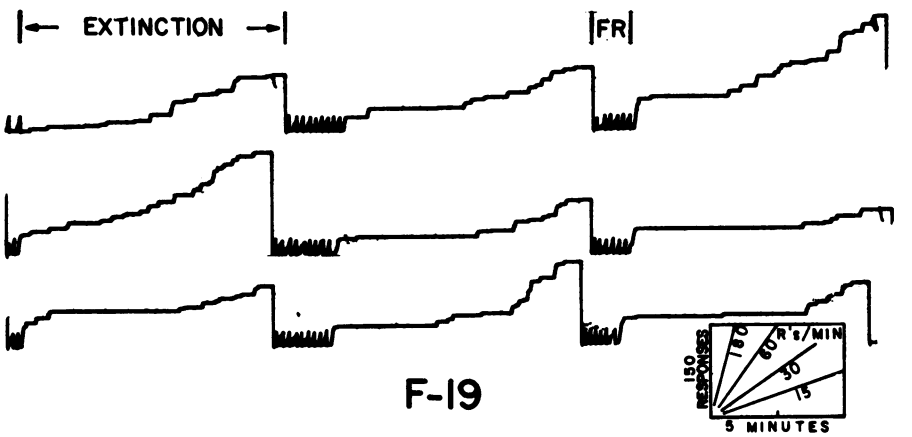

Figure 2. A typical responding during extinction component under mix FR 24 ext 10 minutes.

terminal rate. In general, there is no reason to believe that most of the intervals were much different from those pertaining under an isolated FI schedule (cf., Ferster & Skinner, 1957). A few intervals were somewhat atypical. At *h* and *j*, for example, the subject emitted its first response after the elapse of the 2-minute interval, a fairly common occurrence. The first intervals after each extinction period, however, were consistently irregular. Sometimes (*a* and *e*), little initial pausing took place, and intermediate, rough-grained rates arose, soon giving way to normal terminal rates. At other times (*b* and *f*), pausing did precede the rough, low rates in the interval immediately after extinction and high terminal FI rates failed to develop. Aside from these irregularities, the interval components in Fig. 2 reflect an advanced level of training consistent with the many months of daily running that preceded the illustrated session.

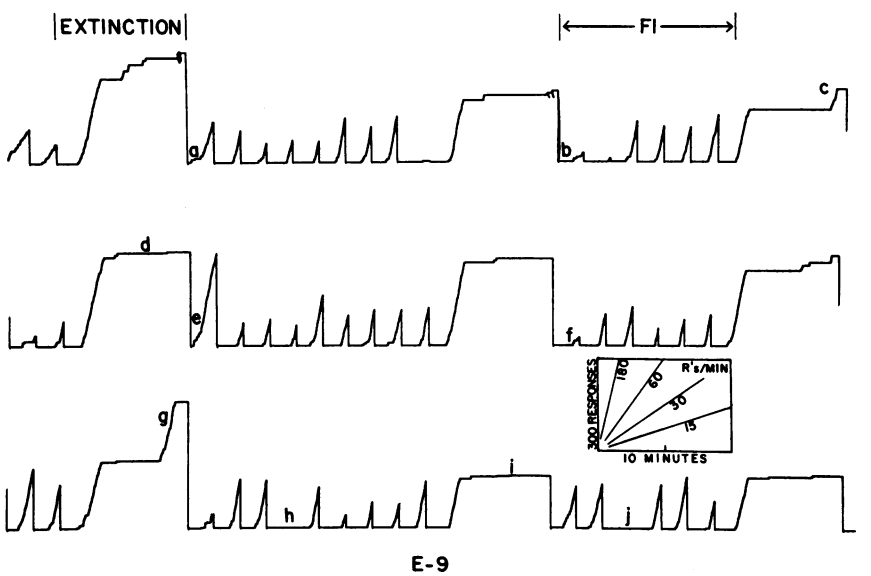

Figure 3. Typical behavior under mix FI 2 minutes ext 10 minutes.

The "trained-extinction" responding bears little or no similarity to one-trial extinction after an extended fixed-interval program (Ferster & Skinner, 1957; Skinner, 1938). After priming runs which followed terminal FI rates, sharp cutoffs in responding occurred. While these breaks very rarely began until 2 minutes elapsed from the onset of extinction, the number of extinction responses emitted before the breaks began frequently was less than or barely reached the total number of responses emitted in many fixed intervals. This would suggest that the temporal factors coincident with the 2-minute fixed interval played an important role in the animals' cessation of extinction responding. Occasionally, no extinction responses were emitted until well after 2 minutes had elapsed (*i* is a moderate example of this); under this circumstance, however, rats invariably emitted more than a handful of responses, indicating that response number in extinction continued to influence extinction responding.

After the initial drastic rate stoppage in extinction, the rats usually failed to emit more than a few responses, small bursts or single responses providing most of the interruptions of the pertaining zero rates (*d* and *i*). Sometimes, extended bursts at rates approximating terminal interval rates (as at *c* and *g*) were seen.

During intervals, rats emitted a mean of from 39.5 to 51.1 responses per reinforcement (Table 1). The considerable variability in the performance of Rat E-11 influenced its response-per-reinforcement score. (Curiously, when later placed on the mixed DRL extinction program, this rat showed very little variability in this measure.) During the session, E-9, E-10 and E-11 emitted many more extinction responses than appeared under the mixed-ratio or DRL schedules. Nevertheless, their large number of FI responses served to reduce the mean number of extinction responses in relation to responses per reinforcement. Thus, these subjects emitted only 2.8 to 3.2 as many responses in extinction as they did, on the average, during each fixed interval.

Mix DRL 20 seconds ext

After stabilization on mix DRL 20 seconds extinction, cumulative curves for Rats E-9, E-10 and E-11 strongly resembled the sample record shown in Fig. 4. The DRL component, it may be seen, was characterized by low and steady rates, with a rather efficient accumulation of 20-second IRT's and resulting reinforcements. On the average, the three subjects required from 1.5 to 2.0 responses to obtain a single S^R (Table 1), a rather creditable performance.

By the time stability was achieved, extinction contained rates which were dissimilar from those pertaining during DRL. Towards the end of extinction, plateaus with no responding appeared (Fig. 4), demonstrating that the 10-minute extinction period was sufficiently long for the subjects to derive feedback from the withholding of reinforcement. Figure 4 indicates also that although long periods of no responding consistently arose in extinction, there were other marked differences among the separate extinction periods. Sometimes, the near-zero rates were the extensions of fairly smooth decelerations in the already low rates characterizing DRL, as at *d*. Other times, they were interspersed with response bursts (*a*, *c*, and *e*). Occasionally, the initial DRL rate first gave way to a very small burst, only to be succeeded by a sustained failure to respond (*b*). The high rates which often arose in extinction, it may be noted, were usually absent during the DRL component itself, giving rise to the speculation that inter-response time distributions under the conditions were not alike, extinction probably containing comparatively more short IRT's.

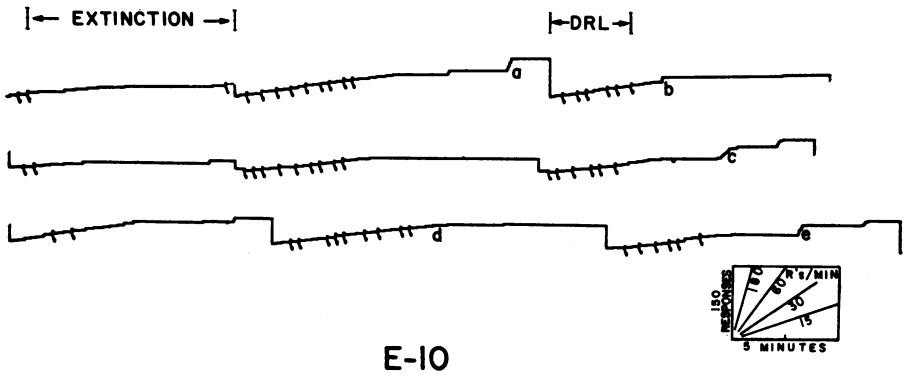

Figure 4. Typical behavior under mix DRI 20 seconds ext 10 minutes.

Table 1 indicates that individually the extinction periods contained from 7.5 to 10.0 responses for each response per reinforcement; that is, the three rats emitted from about 7.5 to 10.0 responses more than were emitted, on the average, to obtain a single reinforcement during DRL.

DISCUSSION

The mixing in of extinction within the three investigated reinforcement schedules appears, after prolonged training, to have little effect in altering the behavior which is generated by the corresponding "pure" schedules. One apparent disruption which has been mentioned, however, is in the first reinforced sequence following extinction in the fixed-interval case (Fig. 3). The occasional breaks in the midst of fixed ratios (Fig. 1, *b*) are perhaps also related to the extinction component, and may represent a premature responding appropriate to extinction. Under each schedule the prolonged exposure to an extinction component results in extinction responding bearing little relation to the sustained responding applying during a single extinction trial.

Under mix FR ext the trained extinction consists of a ratio "priming run" terminating shortly with a sharp break in responding, and followed by a continued failure to respond, except for occasional response bursts, usually at ratio rates. This finding has previously been reported (Ferster & Skinner, 1957). In the present experiment, one subject (Fig. 2) was atypical in that the initial response break during extinction was later followed consistently by sustained, very frequent, short bursts and pauses. Extinction responding, for this subject, gave the appearance of being spuriously reinforced by the light onset which signaled the imminent end of extinction; perhaps the much longer extinction periods used by Ferster and Skinner were instrumental in preventing this phenomenon in their design. Even for Rat F-19, however, the number of responses in the entire 10 minutes of extinction, as well as the number until a clear response break arose, was far less than can be expected from a single 10-minute extinction trial after FR 24.

The FI 2-minute and DRL 20-second schedules led to sharp, rapid cutoffs in responding following appropriate priming runs during the extinction component, contrasting markedly with one-trial extinction on these schedules. The present study shows that after the extinction cutoff, the bursts which are interspersed with long periods of low rates are more

characteristic of the mixed-ratio extinction program than of the more or less gradual decelerations characterizing one-trial FI or DRL extinction. It is of further interest to note that in the case of the mix DRL ext which was used, the response bursts that were rather commonplace in the extinction component usually arose after a long initial pause in extinction, and were virtually nonexistent during DRL itself after stability was reached.

Table 1 shows that the DRL schedule required subjects to emit no more than two responses, on the average, for each reinforcement. Under FR, of course, the mean response per reinforcement closely matched the schedule itself, while the FI that was used led to the greatest response-per-reinforcement ratio. Total extinction responding under each schedule paralleled the response-per-reinforcement data, as would be expected. When mean responses per reinforcement are equated between the schedules, however, the comparative number of extinction responses in every extinction period becomes revealing. The FR and FI are not significantly different in this respect (Mann-Whitney "U" test). On the FR and FI schedules, each extinction component contains, on the average, from 2.6 to 5.3 times the mean number of responses per reinforcement. As stated previously, a ratio of 1.0 would indicate "perfect" discrimination of the no-reinforcement condition, and increasing values suggest a progressively worsening discrimination of extinction onset. Thus, under the DRL program, fully 7.5—10.0 times the mean number of responses emitted per reinforcement are emitted during every extinction period. As Fig. 4 suggests, the bursts of responding well into extinction probably contributed most of these responses; but why such bursts continued to arise remains unexplained.

SUMMARY

Rats were stabilized on each of three reinforcement schedules, mix FR 24 ext 10 minutes, mix FI 2 minutes ext 10 minutes, and DRL 20 seconds ext 10 minutes. The extinction component had little effect upon expected responding during the respective reinforcement components, but came to differ markedly from one-trial extinction. When the reinforcement schedule was FR 24, extinction was characterized by initial ratio "priming runs," followed by a plateau of no responding. As extinction progressed, rapid bursts of responding arose, differing considerably among rats in frequency. Under FI 2 minutes, extinction began with typical fixed-interval priming runs, which ceased abruptly. Mostly short bursts and long pauses were in evidence throughout the remainder of extinction. When responses were reinforced by DRL 20 seconds, extinction consisted, again after an appropriate priming run, of long pauses; but sizable response bursts at high rates—invariably absent during DRL itself—were observed.

A ratio of responses in each 10-minute extinction period to responses per reinforcement showed that rats under DRL emitted far more extinction responses (7.5—10.0) than did either FR (2.6—5.3) or FI (2.8—3.2) subjects, in proportion to the mean number of responses per reinforcement during reinforcement components.

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Received December 30, 1959.