

ESCAPE FROM S^D ASSOCIATED WITH FIXED-RATIO REINFORCEMENT¹

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Throughout ascending and descending fixed-ratio (FR) sequences, rats were allowed to terminate the FR stimulus control by pressing a time-out (TO) lever. To minimize chance or accidental responses on this second lever, three presses were required to produce the 30-sec S^A period. As FR performance became more "strained," there was an increased predisposition to escape from the time-in stimulus complex. The generality of this finding was extended by obtaining recoverability (independent of the direction of stimulus change) of the FR-TO function in the descending series. Typically, escapes were produced only during the post-reinforcement pause; however, under a mixed FR FR schedule, their occurrence shifted to a point within the inter-reinforcement interval corresponding to the unreinforced completion of the lower ratio component. It appears that the point where the rat can discriminate the size of the ratio requirement will be the place where TOs are imposed. This inference was supported by a substantial increase in TO frequency accompanying a shift from CRF to extinction on the FR lever. Finally, the escape lever was placed on a progressively increasing FR schedule and later extinguished to demonstrate that the TO condition was in fact reinforcing.

There are several lines of evidence suggesting that an increase in the ratio requirement of an FR schedule of positive reinforcement produces a concomitant increase in the aversiveness of such contingencies. For example, when two response keys are associated with different values of fixed-ratio (FR 20 and FR 50), pigeons are found consistently to avoid the higher requirement (Herrnstein, 1958). In a different context, Findley (1958) reported a decrease in "switching" to a key which reset a progressive-ratio schedule on another key as the FR reset requirement increased. Concerning the FR "break-burst" pattern itself, it has been argued that the long pause-after-reinforcement (PAR), or "ratio strain," at high FR requirements is due to the suppressive effect of aversive stimuli then present (Ferster and Skinner, 1957).

Perhaps the most convincing demonstration of fixed-ratio aversiveness is that described by Azrin (1961). The underlying assumption

is that a defining property of an aversive stimulus is its ability to reinforce negatively. Azrin allowed pigeons to control the duration of their escape from an S^D associated with an FR schedule. One peck on the escape key produced a "time-out" (TO) condition, during which all responding was ineffective in producing reinforcement; a second peck restored the original S^D contingencies. Two outstanding regularities were noted: (1) the birds spent increasingly more time in TO as the FR increased from 65-200; and (2) escapes were typically restricted to the PAR segment of the inter-reinforcement interval.

The present investigation attempted to extend the generality of the Azrin (1961) results. To allow an evaluation to be made concerning the reversibility of the FR-TO relationship, both ascending and descending FR sequences were employed (Exp. I). Frequency, rather than duration of escape, was chosen as the principal dependent variable to provide a systematic replication. In addition, PAR distributions were concurrently tabulated to determine the extent to which ratio strain and "schedule aversiveness" are related across the FR dimension. For comparative purposes, a mixed FR FR schedule was used to determine whether escapes are produced at that point within the inter-reinforcement interval at

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which the rat can discriminate the size of the FR requirement (Exp. II). Finally, to determine whether the TO condition was in fact reinforcing, the escape bar was placed on a progressively increasing FR schedule, and later extinguished (Exp. III).

METHOD

Subjects

Six male albino rats of the Wistar stock, experimentally naive, and between 105-110 days of age at the beginning of the investigation were used. Experimental sessions were scheduled on alternate days, at which time each S was 23-hr water-deprived. On the days the Ss did not work, they were allowed access to water for 1 hr.

Apparatus

The experimental chamber consisted of a double-lever Skinner box designed to provide water reinforcement. The inside dimensions measured 11 in. long, 11½ in. wide, and 9 in. deep. The operanda were two Gerbrands levers which projected ½ in. into the box, 3¾ in. above the wire-mesh floor, and were spaced 6½ in. from center-to-center. Each operandum requirement was a depression of approximately 15 g of force. Reinforcement was .05 cc of tap water and was delivered by a Lehigh Valley dipper mechanism. The dipper cup, ⅝ in. above the floor level, was exposed through a 1¼ in. diameter aperture positioned equidistant from either lever. The houselight was a suspended, 7-w shielded bulb. To minimize extraneous sounds, a masking stimulus was provided by a Grason-Stadler white-noise generator. The experimental chamber, dipper assemblage, and white-noise speaker were housed in a well-ventilated, aluminum picnic box.

Standard operant programming and recording apparatus was located in an adjacent room. The programming was accomplished by means of relay circuitry, reset-timers, and stepping switches; the recording by magnetic counters and two cumulative recorders. On a bank of 10 additional counters, PAR distributions were recorded in 5-sec intervals.

Preliminary Training

Initially, with only one bar operative, discrimination training was run with all Ss to

establish absence-of-houselight as the S^A. (During later phases of the experiment, Ss could produce S^A as the TO condition by pressing a second bar). A chained DRO 30 sec FR 1 schedule was employed, where houselight-off was the S^A condition in the first link, and houselight-on the S^D condition in the terminal link. Under these contingencies, not only were responses in the dark unreinforced, but also they postponed the presentation of the next S^D in the chain by 30 sec. This type of training was continued until less than 5% of the total responses made during the 2-hr session were occurring in the presence of the S^A-dark condition.

The "Time-out" Paradigm

Next, reinforcement was programmed on an FR schedule on the same bar used in the preliminary discrimination training. At the beginning of FR training, the TO bar was made functional. The TO requirement was set at three presses, which produced 30 sec of S^A. During S^A, responses had no programmed consequence; *i.e.*, neither FR nor TO responses applied to the completion of the ratio requirement or to a postponement of S^D onset. Throughout the following experiments, it is important to keep in mind that at no time were TO responses required in the contingency to produce the water reinforcing stimulus.

EXPERIMENT I

Ascending and Descending Fixed-Ratio Sequences

Procedure. For Ss R-1, R-2, R-3, and R-4, the ratio requirement was gradually increased from FR 1 to FR 25, which served as a baseline for later increases in FR magnitude. After stabilization under FR 25, the requirement on the water bar was progressively increased over sessions, in increments of 25, to a value that produced a sufficient shift in the PAR distribution to indicate that FR performance was extremely "strained". Then, from this maximum work requirement, the FR was decreased in decrements of 25 to the original FR 25 baseline.

As a control for the possible aversiveness of the light-S^D *per se*, that is, apart from its association with the FR schedule, discrimination reversal was run under chained contingencies

identical to those used to establish the original TO condition. Now, with dark as the S^D and three TO responses producing 30 sec of light-S^A, the above-described ascending and descending sequences were repeated. In short, for each S there were four replications: (1) light-S^D:ascending, (2) light-S^D:descending, (3) dark-S^D:ascending, and (4) dark-S^D:descending.

Throughout the above sequences, performance was evaluated in terms of a stability criterion. This allowed no greater than .05 variation of the proportion, TO/TO + S^R, for three consecutive sessions, where TO is the number of escapes imposed, and S^R is the number of water reinforcements produced. Sessions were 2 hr in duration for rats R-1, R-2, and R-3; 4 hr for R-4.

Results. The ratio, TO/TO + S^R, was used as a measure of schedule aversiveness. In a sense, this index represents the proportion of negative reinforcements (*i.e.*, escapes) of the total reinforcements produced. For example, where the TO ratio is equal to or greater than .50, it indicates that at least one escape was imposed per water reinforcement on the average.

Figure 1 shows that schedule aversiveness generally increased in a monotonic fashion as a function of the FR requirement. This observed increase was due both to an increase in the number of escapes (see Fig. 2 inset) and to a decrease in the number of water rein-

forcements. Furthermore, it can be seen that ratio strain, as measured by PAR > 50 sec, also increased as a function of FR magnitude. These relatively long post-reinforcement pauses occurred very infrequently at the low ratio requirements. However, with one exception (S R-4), at least 95% of the total PARs at the highest FR were greater than 50 sec in duration. Subject R-4 never did show the extreme ratio strain (long PARs) of the other Ss even though its maximum requirement was the highest of the four rats. This S was also unique in both FR rate and response topography. Its rate sometimes reached as high as eight responses per sec in contrast to terminal rates of not more than five responses per sec for the other rats. Casual observation revealed that the topography of R-4 consisted of "fluttering" the bar with one paw above and one below. The other three Ss typically placed both paws above the lever in operating it.

With respect to both the TO ratio and PAR, the descending sequences successfully recovered ascending values; this was the case regardless of the direction of stimulus change. Thus, since the interest was in stable performance, and inasmuch as reversibility was demonstrated, the data were summed such that each data point in Fig. 1 represents the average of the four S^D-sequence conditions for the last session before the requirement was shifted.

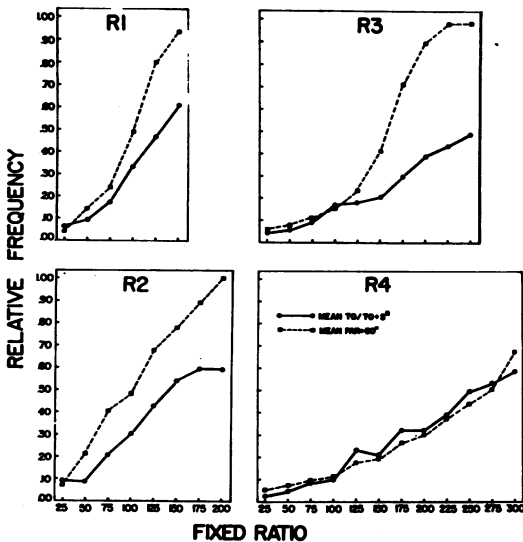


Fig. 1. Covariation of "schedule aversiveness" (solid) and "ratio strain" (dashed) as a function of the fixed-ratio requirement.

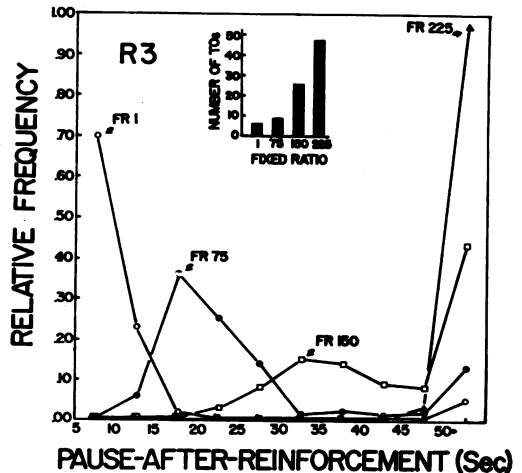


Fig. 2. Shifts in pause-after-reinforcement distributions across the fixed-ratio dimension. The inset shows the corresponding number of TOs imposed at each ratio requirement. The data points are based on the final performance at each fixed-ratio value of the dark-S^D: ascending sequence.

Figure 2 illustrates the typical shift of the entire PAR distribution across the FR dimension. The inset shows the corresponding number of TOs produced at each ratio requirement. The "0-5" bin was not included in the analysis as casual observation revealed that the *S* spent about 5 sec drinking after a reinforcement regardless of the ratio requirement. Hence, a count in this bin would indicate a reinforcement "run through" rather than a short post-reinforcement pause. In comparing the four distributions, one qualitative feature stands out in particular. At the extremes (FR 1 and FR 225), the distributions are relatively steep and bear almost a "mirror-image" relation to each other. However, this monotonicity is disrupted in the middle range (FR 75 and FR 150), and there is a progressive flattening of the distributions. Finally, it should be noted that "PAR > 50" was the only bin that covaried with the number of TOs (see inset) as a monotonic increasing function of the ratio requirement.

To appreciate other aspects of escape responding in relation to the FR requirement, typical collapsed cumulative records are pre-

sented in Fig. 3 for one *S*. Perhaps the most significant aspect (other than the marked increase in TOs as a function of the ratio requirement) is that TOs, almost without exception, were imposed only at a particular point within the inter-reinforcement interval; namely, during the post-reinforcement pause. In other words, once the *S* began its high terminal rate of response, this continued uninterrupted until reinforcement. Exceptions, as at *f*, where four TOs were imposed after about 25 ratio responses had been emitted, were extremely rare, and seemed to be limited in their occurrence to the higher FR values.

Also, it should be noted that instances of escapes being made in succession within a single post-reinforcement pause appeared to increase as a function of the ratio requirement; *i.e.*, *b* and *d* tendencies increased as the *S* was required to work more. Thirdly, at FR 25, the preponderance of escape responding occurred toward the end of the session, or after a considerable number of reinforcements had been received. However, at the other extreme (FR 250), escapes became more or less equally

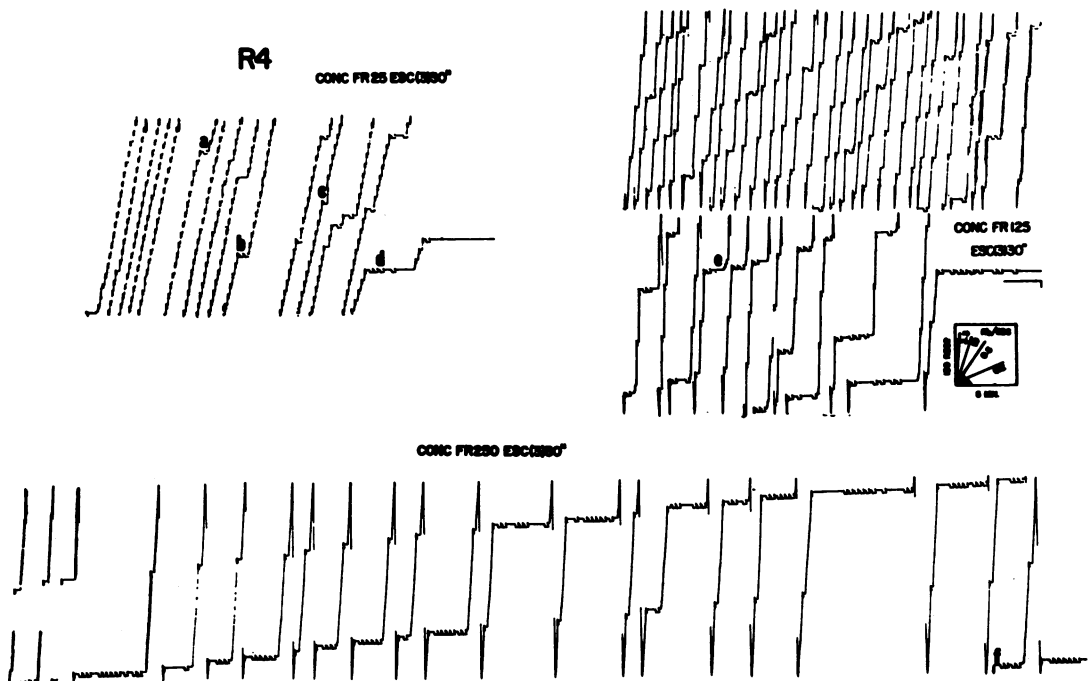


Fig. 3. Escape responding at low, moderate, and high ratio requirements. Each pen excursion represents about 475 responses; the oblique blips indicate water reinforcements, and the downward displacements show where the 30-sec TOs were imposed, as at *a*. The curves show the final performance at each fixed-ratio value of the light-*S*^o: ascending sequence.

distributed throughout the session. At all ratio requirements, occasionally the S responded on the water bar during TO, as at *c*. In contrast, inspection of a second cumulative record of TO responding (not shown) indicated that responding on the TO bar during TO rarely occurred. Finally, at moderate and high ratio requirements, there were frequent instances of uneven grain, as at *e*, again suggesting that FR performance was strained.

EXPERIMENT II

Comparison of Mixed and Straight Fixed-Ratio Contingencies

Procedure. One rat (R-1) was exposed to mixed FR 25 FR 225 contingencies before the straight FR sequences were instituted. Under this schedule, a low and high ratio component were randomly alternated without an exteroceptive S^D indicating which requirement was in effect at a given time. The 2-hr sessions were continued until stability was demonstrated. Then, R-1 was run under a straight FR 225 schedule, and stable performance was evaluated by the TO-ratio criterion of Exp. I. Throughout both the mixed and straight FR paradigms, the TO requirement was three, the S^D was houselight-on, and the TO duration remained constant at 30 sec.

Results. Figure 4 compares FR 225 performance with FR 25 FR 225 performance for the final session on each schedule. As previously noted (Fig. 3), under straight FR contingencies, TOs were restricted to the post-reinforcement pause. Single and double occurrences are shown at *a* and *b*, respectively. In contrast, under the mixed schedule, an entirely different pattern emerged; namely, escapes were imposed in the FR 225 component only after at least the emission of 25 responses (the lower ratio). Examples corresponding to *a* and *b* are illustrated at *c* and *d*. In no instances were TOs produced in the FR 25 component.

In terms of PAR in the higher mixed component, pauses characteristic of straight FR 225 were essentially "displaced" to a point within the inter-reinforcement interval corresponding to the unreinforced completion of the lower ratio. Pauses typical of straight FR 25 contingencies occurred after reinforcement, and before the initial run. On the other hand, in the lower mixed component, pauses

were always equivalent to those produced under a straight FR 25 requirement.

EXPERIMENT III

Increasing the Time-Out Requirement and Extinction

Procedure. Subject R-5 was exposed to an ascending FR sequence until no water reinforcements were produced during a 1.5-hr session. During this sequence, the ratio requirement was increased by 25 with each succeeding session, instead of allowing stabilization to occur at each FR value. This was done since the interest was in finding a "break-

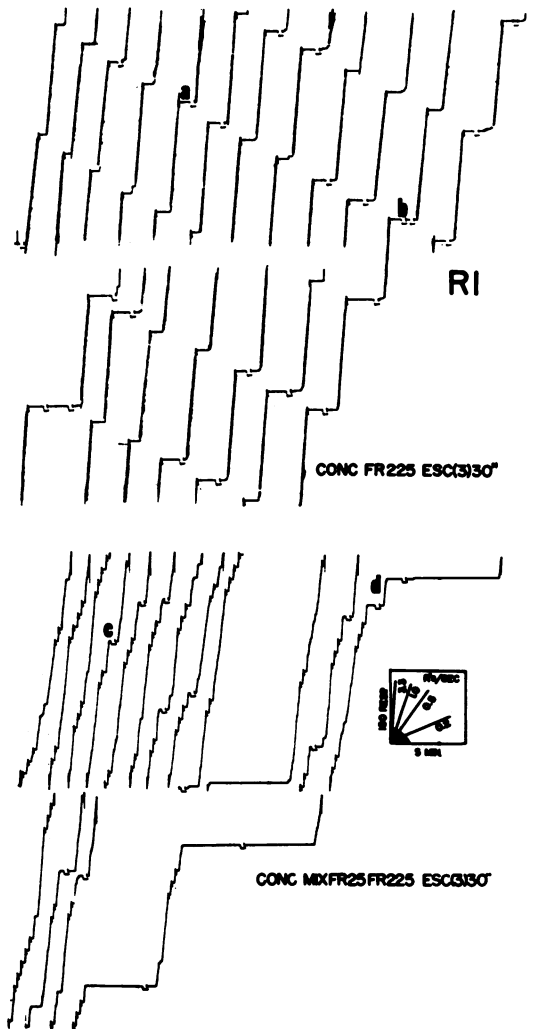


Fig. 4. Comparison of straight (upper record) and mixed (lower record) fixed-ratio contingencies within an individual S.

ing point" (no reinforcements produced) rather than in allowing recovery via a descending FR sequence. Holding constant the FR at this breaking-point value (FR 475), the TO requirement was increased from three to a value just sufficient to eliminate escapes entirely. Throughout this phase, the S^D was houselight-on, and the TO duration remained constant at 30 sec.

Subject R-6 was run under FR 1 (CRF) on the water bar, while three presses on the escape bar produced 30 sec of dark- S^A . After there were no consistent day-to-day changes in performance, 25 CRF reinforcements were given (baseline recovery) in the next session, after which the water bar was extinguished. In the following session, after a second base-

line recovery, both bars were made non-functional.

RESULTS

The top cumulative record in Fig. 5 shows FR and TO performance at the ratio requirement just below the S's breaking point. After starting the first run, an escape was imposed (at *a*), thus interrupting the high rate of response. At *b*, the "bite" in the curve suggests severe ratio strain. From this point until reinforcement, the performance was characterized by marked uneven grain. During the first post-reinforcement pause, 10 widely spaced TOs preceded a burst of 21 escape responses, at *c*. Then, high terminal rates pre-

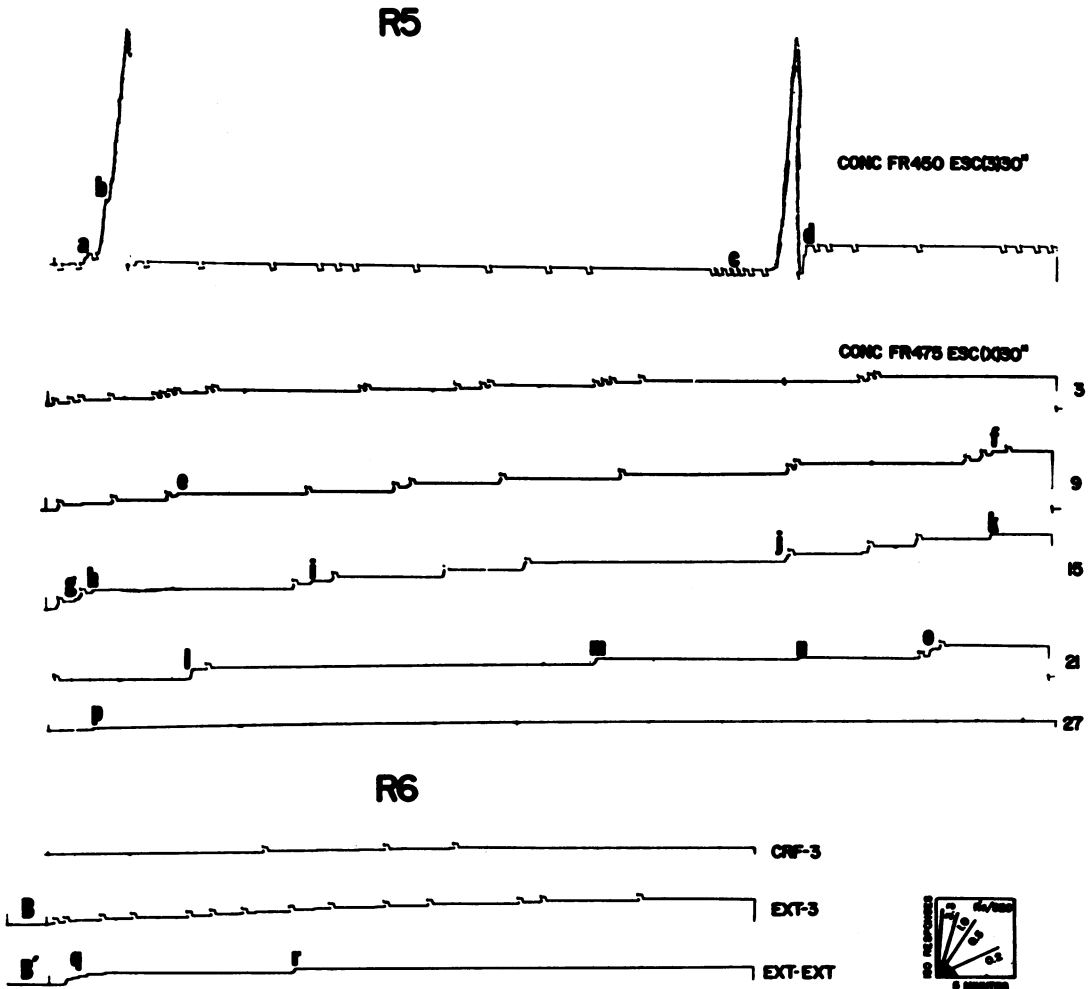


Fig. 5. Escape responding under an extremely high ratio requirement (top curve), under a progressive increase in the TO requirement (the next five curves), and under extinction on one or both levers (bottom three curves). For further details, see text.

ailed until the second reinforcement. The second PAR was atypically short, and except for about 50 ratio responses which ended at *d*, TOs dominated the remainder of the session.

The next five cumulative records in Fig. 5 depict TO responding for TO requirements of 3, 9, 15, 21, and the second breaking-point value, 27. (No water reinforcements were produced at any of these TO requirements). As can be seen, TO responding increased to a maximum at $x = 15$, and then decreased to essentially zero at the TO breaking-point value. At $x = 3$, all escapes occurred in typical FR bursts. However, when the TO requirement increased to nine, these bursts were occasionally interrupted, as at *e* and *f*. Evidence of straining was more frequent at $x = 15$, such as at *g*, *h*, *i*, *j*, and *k*. When 21 responses were required to impose TO, in no cases were escapes made without atypical FR performance, as the "knees" at *l*, *m*, *n*, and *o* show. Finally, when the TO requirement was 27, the *S* avoided both levers entirely, with the exception of a single escape response at *p*.

The bottom three curves of Fig. 5 show the effect of extinction on TO performance when either one or both bars were made non-functional. Only three escapes were imposed on the final day of CRF-3. After baseline recovery (B), the effect of extinction on the water bar was an immediate increase in escape responding, which continued throughout the session. Finally, when both bars were made non-functional after a second baseline recovery (B'), TO responding began shortly after the first reinforcement was "missed". At *q*, there was a burst of responses typical of extinction after exposure to a small FR schedule, and the only remaining indication of escape tendencies was the trickle of responses at *r*. It should be noted that in neither B nor B' did any instance of escape occur.

DISCUSSION AND CONCLUSIONS

In general, the results indicate that although an FR schedule is positively reinforcing to an extent sufficient to maintain typical break-burst performance, it possesses at the same time, aversive properties in that it reinforces behavior which removes the FR stimulus control. When the number of escapes are multiplied by the TO duration, it is clearly seen that the relative proportion of session

time spent in S^A increases as a function of FR magnitude. This is consistent with Azrin (1961) and suggests that the degree of aversiveness of the time-in stimulus complex increases as the work requirement is made more demanding. Also in agreement with Azrin, it was found that TOs were generally restricted to the PAR segment of the inter-reinforcement interval. Finally, both studies rule out adventitious reinforcement and the direction of stimulus change as alternative interpretations of the data; the former because FR responding necessarily imposed a delay between escapes in PAR and the reinforcing stimulus, and the latter because TOs were produced regardless of whether the S^D was light or dark.

The present investigation extends the generality of the ascending-sequence data obtained in the Azrin procedure by demonstrating recoverability of the function relating time-out to the ratio requirement in the descending sequence. Still, on the basis of Exp. I and the Azrin results alone, it could be argued that the longer post-reinforcement pause at the higher ratio requirement did nothing more than provide a greater opportunity for "operant-level" responding to occur on the non-FR bar. However, the TO requirement and extinction data of Exp. III suggest otherwise. When the TO requirement was increased to 15, responding on the TO lever increased in characteristic break-burst fashion. Conversely, when the TO lever no longer produced stimulus change under FR 3, typical extinction responding occurred. There is no reason to expect comparable operant-level shifts as a result of either experimental manipulation (Pliskoff and Tolliver, 1960).

It is interesting to note that the general restriction of TO responding to the PAR segment of the inter-reinforcement interval can be abolished by an appropriate producing operation; specifically, by shifting the aversive baseline from a straight FR contingency to a mixed FR schedule. It appears that the point within the inter-reinforcement interval where the rat can discriminate the size of the ratio requirement will be the place where pausing occurs, and hence where TOs are predominantly imposed. A mixed schedule demands that the rat discriminate the size of the FR on the basis of its own responding. Only after the lower requirement has been "counted off"

unreinforced can the rat "know the score" (Skinner, 1953). This account seems even more plausible inasmuch as it has been demonstrated in several experimental contexts that a rat is capable of such a "count discrimination" (Mechner, 1958). In contrast, under straight FR contingencies, the reinforcing stimulus itself seems sufficient to indicate the amount of work "in store" for the rat.

The finding that escapes occurred with greater frequency after a considerable number of reinforcements had been received (Fig. 3, FR 25) suggests an interaction between the ratio requirement and satiation. In light of the concomitant variation of PAR and TO responding, these data are consistent with the reported increase in PAR under low FR values as a function of either prewatering or extended experimental sessions (Sidman and Stebbins, 1954). Moreover, if it is assumed that satiation decreases reinforcement efficacy, this observation is in agreement with the finding that escapes from a fixed-ratio S^D increase when the baseline reinforcement is made ineffective (Pliskoff and Tolliver, 1960).

In conclusion, it seems that self-imposed TO is a sensitive, convenient, and direct procedure for measuring the concomitant aversive properties of FR schedules of positive reinforce-

ment. One important implication is that any stimulus associated with positive reinforcement contingencies may possess certain aversive characteristics in addition to its discriminative properties.

REFERENCES

- Azrin, N. H. Time-out from positive reinforcement. *Science*, 1961, **133**, 382-383.
- Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Findley, J. D. Preference and switching under concurrent scheduling. *J. exp. Anal. Behav.*, 1958, **1**, 123-144.
- Herrnstein, R. J. Some factors influencing behavior in a two-response situation. *Trans. N. Y. Acad. Sci.*, 1958, **21**, 35-45.
- Mechner, F. Probability relations within response sequences under ratio reinforcement. *J. exp. Anal. Behav.*, 1958, **1**, 109-121.
- Pliskoff, S. and Tolliver, G. Water-deprivation-produced sign reversal of a conditioned reinforcer based upon dry food. *J. exp. Anal. Behav.*, 1960, **3**, 323-329.
- Sidman, M. and Stebbins, W. C. Satiation effects under fixed-ratio schedules of reinforcement. *J. comp. physiol. Psychol.*, 1954, **47**, 114-116.
- Skinner, B. F. Some contributions of an experimental analysis of behavior to psychology as a whole. *Amer. Psychologist*, 1953, **8**, 69-78.

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