STRATEGIES OF SCHEDULE PREFERENCE IN CHIMPANZEES[1]

WILLIAM HODOS AND GERALD H. TRUMBULE

UNIVERSITY OF MARYLAND

Two chimpanzees were required to choose between a fixed-ratio schedule and a progressive-ratio schedule which increased in response requirement by 20 responses each time it was chosen. Each choice of the fixed ratio reset the progressive ratio to its minimum value. The fixed-ratio requirement was varied from 40 to 1000 responses. The subjects' preferences for the progressive-ratio schedule varied as a function of the magnitude of the fixed-ratio requirement. An analysis of the preference data indicated that the animals tended to minimize reinforcement cost rather than match the progressive-ratio requirement to the fixed-ratio requirement. In a second experiment, selection of the fixed ratio did not reset the progressive-ratio requirement to its minimum value. In this case, the animals matched the progressive-ratio requirement to the fixed-ratio requirement. A model based on reinforcement cost is presented which permits accurate prediction of preferences between fixed and progressively increasing ratio schedules.

The study of the selection by experimental organisms of certain reinforcement contingencies in preference to others may be viewed as a necessary step in the development of methods for the eventual control and prediction of complex behavior outside of the laboratory. Such choice behavior, or schedule preference, is a common feature of life in a naturalistic environment where various alternative methods of obtaining the same reinforcer are often simultaneously available.

Much of the recent work on concurrent reinforcement schedules (Herrnstein, 1961; Catania, 1962) has been directed at the problem of schedule preference. These techniques permit the subject to choose between two manipulanda which have been programmed on independent, concurrent schedules. In the case of variable-interval schedules, the relative response rates on the two manipulanda may be taken as an index of schedule preference. A related technique permits the subject to change the schedule on which a single ma-

nipulandum has been programmed by operating a second manipulandum. This second manipulandum may also be programmed on some schedule, and such "switching" responses taken as an index of schedule preference (Findley, 1958; Catania, 1963). A number of investigators have devised models of schedule preference which will permit accurate, quantitative predictions of performance (Herrnstein, 1961; Catania, 1963). These models have been based on the observation that the response rates maintained by the two schedules are proportional to the rates of reinforcement they provide.

The Herrnstein and Catania models describe performance on variable-interval schedules in which the rate of reinforcement is largely under the control of the experimenter. The present report attempts to develop a model for the control and prediction of schedule preference when rate of reinforcement is exclusively determined by the subject. The subjects were confronted with a choice between two mutually exclusive ratio schedules. The response requirement of the first schedule was initially less than the second, but became progressively higher each time it was chosen and could eventually exceed the second. The response requirement of the second schedule remained constant. After each reinforcement, the subject could select either the schedule with the progressively increasing requirement

or the schedule with the fixed requirement. The measure of schedule preference was the point in the progression at which the subject switched from the progressive to the fixed schedule. The data were compared to theoretical switching curves based on such "strategies" as a comparison by the subject of individual reinforcement costs, minimization of reinforcement costs over large behavioral segments, maximization of reinforcement rate, *etc.* A model was developed based on the maintenance of a constant value of the reinforcement cost per ratio run. This model permits accurate predictions of the preferences among fixed and progressively increasing ratio schedules when the organism has the option of resetting the progressive contingency. When the subject is not permitted to reset the progressive schedule, performance is based solely on the cost of individual reinforcements.

METHOD

Subjects

Two chimpanzees, each with extensive experience with a variety of experimental contingencies for food, water, and social reinforcers, were used. Penny, a female, was about 5 yr old at the start of the experiment and weighed approximately 34 kg. Kenny, a male, was about 8 yr old and weighed approximately 57 kg.

Apparatus

The subjects were individually housed in experimental chambers, 1.83-m long by 1.83-m wide by 2.44-m high, which provided continuous temperature and humidity control and moderate acoustical insulation. The cages were cleaned daily, but at all other times the chamber doors remained closed, and the subjects were in isolation. During the cleaning period, the animals were given Poly-vi-sol liquid vitamins orally.

A response panel was situated on the rear wall of each chamber above a bench, on which the animal could sit and manipulate the various switches. A diagram of the panel is shown in Fig. 1. The manipulanda were toggle switches mounted on translucent Plexiglas discs behind which were different colored stimulus lights. Each toggle switch was functional only when its surrounding disc was illuminated. Water was available upon depression of the water switch while the surrounding stimulus light was lighted, but subjects were permitted to obtain water only during specified periods as described later.

The reinforcement contingencies were controlled by a system of relays, timers, and stepping switches. Responses were recorded on direct read-out counters, printing counters, and cumulative recorders. The progressive ratios were programmed on a Tally Model 424 tape reader (Swinnen and Hodos, 1967). The tapes were programmed for a maximum of 40,000 responses without resetting.
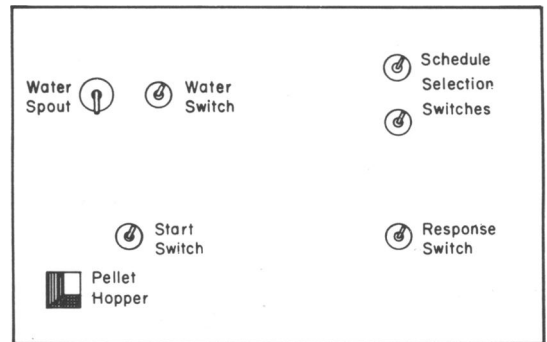

Fig. 1. A schematic drawing of the response panel.

Procedure

At each choice-point in the experiment, the animals were required to choose between one of the two schedules: (1) a fixed-ratio (FR) schedule in which the number of responses necessary to produce reinforcement remained fixed throughout the session; or, (2) a progressive-ratio (PR) schedule (Findley, 1958; Hodos, 1961; Hodos and Kalman, 1963) in which the response requirement increased by 20 responses each time that schedule was selected. For example, on a given day the FR might have a requirement of 100 responses. The PR always had a requirement of 20 responses the first time it was chosen, 40 responses the second time, 60 responses the third, 80 the fourth, *etc.* Thus, after three PR selections in succession, the animal would have a choice between 80 responses on the PR schedule or 100 responses on the FR schedule. Each choice of the FR schedule reset the PR to the minimum value of 20 responses. The reset of the PR schedule also served to define the "switching point" and to initiate a new progression.

Each daily session was begun by illumi-

nating the disc surrounding the water switch and the start switch (see Fig. 1). No other switches were functional at this time. After 10 responses on the start switch, both the water and start switch stimulus lights were turned off, and the discs surrounding the two schedule selection switches were illuminated. One light was yellow and the other green. The location of the yellow or green lights on the upper or lower discs at each choice point was determined by a quasi-random sequence. One response on the switch with the green light would establish the FR schedule on the response switch below. One response on the switch with the yellow light would establish the PR on the response switch. As soon as one of the schedule selection switches was depressed, the stimulus light behind the other was turned off and a light of the same color appeared on the disc surrounding the response switch. Whenever the PR was at its minimum value (20 responses) the yellow light was flashed on and off at a rate of six flashes per second; when the PR requirement was more than the minimum, the yellow light was on continuously.

After selection of the schedule, the appropriate number of responses on the response switch resulted in the delivery of the reinforcer (five D&G Special Monkey Tablets) into the pellet hopper. At this time, the schedule-selection and response-switch lights were turned off and both the water and start switch stimuli were again illuminated. A new cycle could now be started by 10 responses on the start switch. Responses which occurred out of sequence (*e.g.*, schedule selection responses emitted before 10 responses on the start switch) had no effect on the reinforcement contingencies. Simultaneous depression of two or more switches was also ineffective.

Throughout both experiments, the FR requirement remained constant for five consecutive daily sessions. The sequence of presentation of the various FR requirements was determined randomly with the restriction that the difference between successive FR requirements should not exceed 600 responses. On any given day, the same contingencies were in effect for both animals.

Training

Because of the animals' previous experimental histories, almost no preliminary training was necessary. However, a period of two weeks was allowed for the animals to learn the proper sequence of switch operations and to come under the control of the various stimuli and reinforcement schedules. At the end of this time the cumulative records indicated clearly that the two chimpanzees were responding appropriately to the various contingencies.

Each daily session lasted 8 hr. No limit was placed on the number of reinforcements which could be obtained during this period. Both subjects maintained themselves well on their earned reinforcements, and supplementary feeding was rarely necessary. No deprivation other than the 16 hr preceding the session was required to maintain a large behavioral output.

Terminology

To facilitate data analysis, each session was divided into a number of functional units which are defined below:

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RUN:	A sequence of FR or PR responses terminated by reinforcement.
BLOCK:	A sequence of PR runs followed by an FR run. The completion of the FR run terminated the block.
RUNS PER BLOCK:	The number of runs per block is equal to the number of PR runs plus the one FR run.
REINFORCEMENT COST PER BLOCK:	The total number of responses per block divided by the total number of reinforcements per block.
EQUALITY POINT:	That point in a block at which the PR requirement equals the FR requirement.
SWITCHING POINT:	That point in the block at which the subject switches from PR to FR.
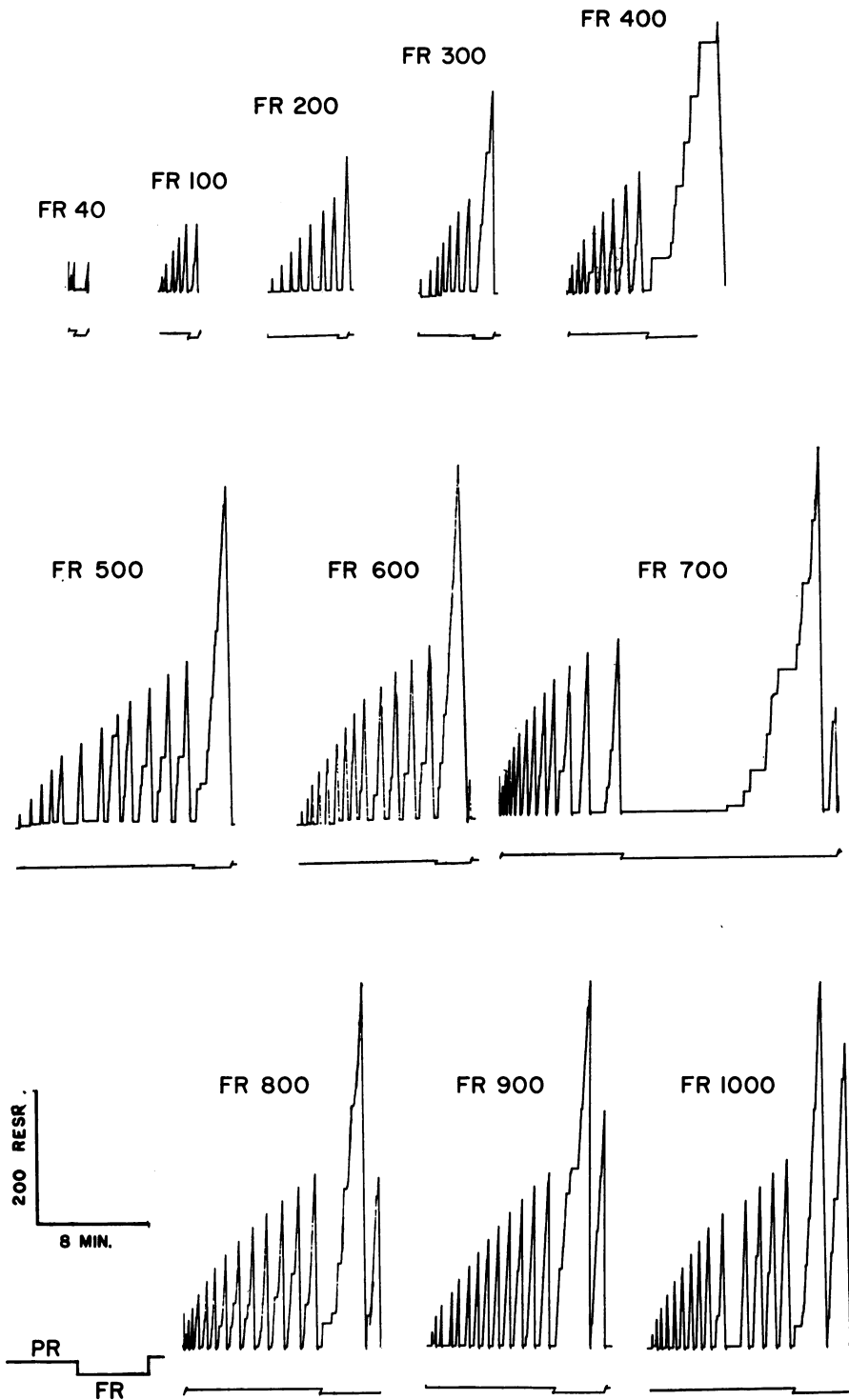
Fig. 2. Representative cumulative records of Kenny's performance during the final session at each value of the fixed ratio. The progressive-ratio increment is 20 responses in each case. The offset portion of the event marker below each record indicates the point of selection of the fixed ratio. The return to baseline indicates the completion of the fixed-ratio run and the end of the block. See text for definitions of "run" and "block."

EXPERIMENT I
PROGRESSIVE RATIO WITH RESET
OPTION

In the first experiment, the FR requirements were 100, 400, 800, 700, 200, 40, 300, 900, 1000, 500, and 600 responses, in that order. The principal datum was the number of runs per block.

Results and Discussion

Representative cumulative records of Kenny's performance on the final day at each value of the FR requirement are presented in Fig. 2. Each cumulative record depicts one block. The offset portion of the event marker below each record indicates the time from the selection of the FR schedule until the delivery of reinforcement at the end of the FR run. These records indicate that both total responses per block and time per block increase gradually as a function of the FR requirement. Also evident is the fact that as the FR requirement increased, the animals tended increasingly to switch from PR to FR in advance of the equality point.

In Fig. 3 the number of runs per block for each animal has been plotted as a function of the FR requirement. Each data point represents the mean of the five sessions at that FR requirement. Also included in the figure are two theoretical curves representing some possible "strategies" of schedule preference. The data of both chimps indicate that the number of runs per block increased over most of the range of FR requirements, although the curves tend to level off at the higher FR values.

The theoretical curve labeled $PR_i = FR$ indicates what performance would have been like had the subjects selected the FR schedule at the equality point; *i.e.*, at the point at which an individual PR requirement (PR_i) was equal to the FR requirement. Although the $PR_i = FR$ curve seems to describe the data well at the lowest values of the FR requirement, the major portions of the empirical curves fall far below this line. This indicates that over most of the range of FR values, the animals were selecting the FR schedule well ahead of the equality point. Another possible strategy could be based on minimization of reinforcement cost over the entire block. For each FR requirement, the function relating
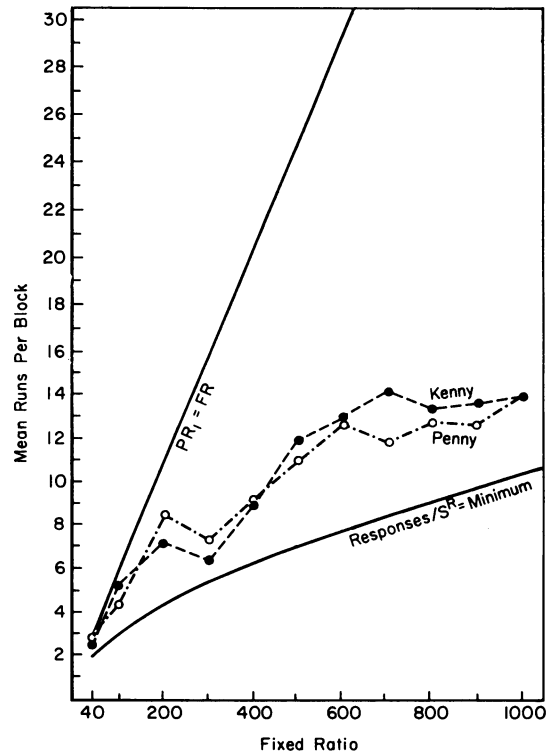

Fig. 3. The results of Exp. 1. The performance of each animal is plotted (broken lines) as a function of the fixed-ratio requirement. The data are compared to two theoretical switching curves (unbroken lines) based on different "strategies" of schedule preference.

reinforcement cost per block to number of runs per block passes through a minimum. A family of such functions from FR 40 to FR 1000 is shown in Fig. 4. The arrow on each curve indicates the number of runs per block at which reinforcement cost is at its minimum value. At each FR requirement, the number of runs per block at minimum reinforcement cost represents the optimal point to switch from PR to FR if the subjects are to obtain the greatest number of reinforcements for the fewest responses within a given block. The minima have been plotted in Fig. 3 for each value of the FR requirement and the points joined to form the theoretical curve labeled RESPONSES/S^R = MINIMUM. This curve has roughly the same shape as the empirical curves, but generally falls short of the empirical switching points by a considerable amount.

Although the empirical curves in Fig. 3 do not fit either of the suggested theoretical strategy curves, they do appear more similar to
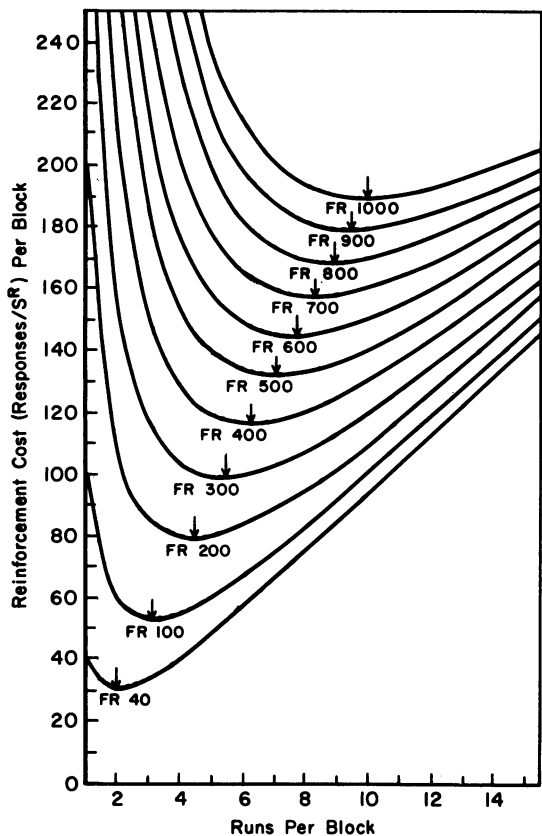
Fig. 4. Reinforcement cost per block is shown as a function of the number of runs per block for each value of the fixed-ratio requirement used in Exp. 1. The arrow on each curve indicates the point in the progression at which reinforcement cost per block is minimal. See text for definition of "reinforcement cost per block."

the minimum reinforcement cost function than to the $PR_1 = FR$ function. This suggests that the actual strategy employed by the subjects may have been based more on some form of cost minimization than on a simple matching of ratio requirements. Moreover, Fig. 4 provides a possible explanation for the deviation of the empirical curves from the minimum reinforcement cost curve. At the low FR requirements, the slopes of the curves in Fig. 4 change rapidly in the vicinity of the minimum values. However, as the FR requirement increases, the curves tend to become rather flat in the vicinity of the minimum. Thus at FR 40, switching from PR to FR one run later than the optimum would result in a 13.3% increase in reinforcement cost; whereas at FR 1000, switching one run later than optimum would only increase reinforce-

ment cost by about 0.5%; *i.e.*, a reinforcement cost of 191 responses *vs* 190 responses. Indeed, at FR 1000, it would be necessary to overestimate the optimum number of runs per block by six runs in order to produce the same percent change in reinforcement cost as overestimating the optimum by one run at FR 40 would produce. Although the empirical curves in Fig. 3 exceed the optimum by approximately four runs per block at FR 1000, this represents an error of only 5% on a basis of reinforcement cost.

Since the Herrnstein (1961) and Catania (1963) models were based on rates of responding and rates of reinforcement, the data were analyzed to determine whether or not these variables were systematically related to the switching performance of the subjects. Responses per minute and reinforcements per minute in each schedule were determined by measuring the PR time and the FR time per block on the cumulative records. The obtained time values were divided into the number of PR or FR responses per block to determine responses per minute and into the number of PR or FR reinforcements per block to determine reinforcements per minute. These data are plotted in Fig. 5. The PR rates are indicated as filled circles and the FR rates as open circles. Unfortunately, the recorder chart
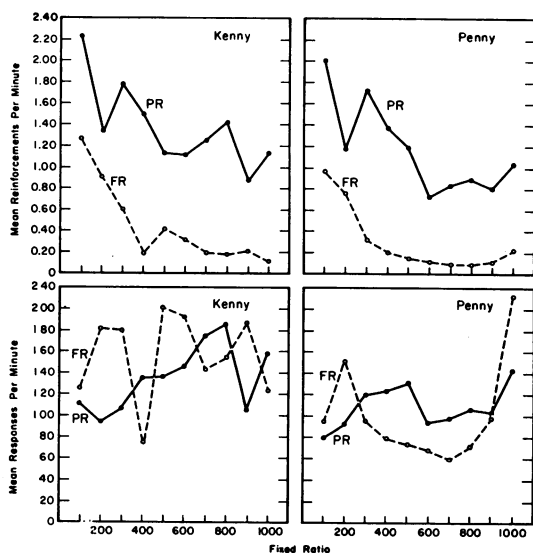

Fig. 5. Response rates and reinforcement rates are plotted as a function of the fixed-ratio requirement. Open circles represent fixed-ratio rates and filled circles represent progressive-ratio rates. Top: mean reinforcement rates. Bottom: mean response rates.

speed was too slow to permit accurate measurement of the FR and PR times at FR 40, and no data points for this FR requirement appear in Fig. 5.

The lower half of Fig. 5 indicates changes in mean response rates on the PR and FR schedules at each value of the FR requirement. Kenny's PR response rates generally increase as a function of the FR requirement. However, there appears to be no systematic relationship between his FR response rates and the FR requirement. Penny's response rates seem to have a complex, non-monotonic relationship with the FR requirement.

The upper half of Fig. 5 describes the changes in reinforcement rates as a function of the FR requirement. Both the FR and PR reinforcement rate functions in both animals exhibit a generally downward trend as the FR requirement increases.

As may be seen in Fig. 5, the response rates and reinforcement rates are generally quite different on the PR and FR schedules. This difference in rate, combined with the progressively increasing response requirements of successive runs, results in a point of maximum reinforcement rate in the progression. Indeed, curves which depict changes in reinforcement rate per block as a function of the number of runs per block are roughly the inverse of the curves of reinforcement cost per block shown in Fig. 4. However, an important difference is that the exact shapes of the reinforcement rate functions depend upon the empirical rates of responding, whereas the reinforcement cost curves depend only on the values of FR and PR selected by the experimenter. Such a family of reinforcement rate functions and their respective maxima could be used to plot a theoretical switching function, just as was done for reinforcement cost as shown in Fig. 3. In such an analysis, the absolute rates of responding are unimportant. The number of runs per block which will result in the maximum reinforcement rate will be affected only by the difference between the FR and PR rates. In order to produce the montonically increasing switching function required to describe accurately the schedule preference data shown in Fig. 3, the PR response rate would have to be the higher in each case and the difference between the FR and PR response rates would have to increase monotonically. As may be seen in the lower half of Fig. 5,

such a systematic relationship between FR and PR response rates does not exist. On the other hand, in a number of instances the differences between the response rates on the two schedules are in the correct direction and are of an appropriate magnitude to result in a fairly accurate prediction of the observed schedule preferences. However, in general, the predictions based on maximization of reinforcement rate tend to underestimate the empirical switching function somewhat more than the minimum reinforcement cost curve.

EXPERIMENT 2
PROGRESSIVE RATIO WITHOUT RESET OPTION

Experiment 2 sought to determine the effects on schedule preference of eliminating the PR reset contingency. The general procedure was the same as in Exp. 1 with the following exceptions: first, the PR requirement was at its maximum value (20 responses) only at the beginning of each daily session. Termination of an FR run resulted only in the delivery of the reinforcer (five pellets) and had no effect on the value of the PR requirement. Second, the FR requirements were 600, 100, 400, 200, 500, and 300 responses, in that order. The subjects remained at each value of the FR requirement for 10 sessions.

Results and Discussion

Eliminating the PR reset contingency posed certain problems in the analysis of the data, since the reset contingency had provided a clear indication of the end of a block and also permitted the examination of many blocks per session. Therefore, in order to determine the point at which the subjects switched from PR to FR, the runs of each session were arbitrarily divided into successive groups of 10 runs each. The percentage of FR and PR runs in each group was plotted on a graph. The point at which the PR and FR selections were both at 50% was regarded as the switching point (*i.e.*, the end of a block). This method of analysis is illustrated in Fig. 6. The number of runs emitted at the switching point (as defined in Fig. 6) was then recorded. This is essentially the same as regarding the ratio progression as an ascending method of limits and determining the 50% threshold point. The results of this analysis

are presented in Fig. 7. The curve $PR_i = FR$ (corrected for the elimination of the FR run from the computation of runs per block) represents the theoretical performance of the subjects if they were matching the PR requirement to the FR requirement. A single curve representing minimum reinforcement cost cannot be plotted since in Exp. 2 only one block is permitted in any given session. The point in the progression which would result in the minimum reinforcement cost would be the same as in Exp. 1 if the animal stopped responding at that point. Any further responding on either schedule would then increase reinforcement cost. Thus, the animals could minimize reinforcement cost per block only by terminating their performance for the day after two reinforcements at FR 40 and eight reinforcements at FR 600. Since the animals rarely received supplemental feeding they would certainly disregard such a strategy. In order to earn more reinforcements per session at the lowest cost, the animals would have to choose the PR until it was equal to the FR requirement and thereafter select the FR exclusively. Although the exact value of the minimum reinforcement cost would depend upon the total number of FR selections after switching, the switching performance itself would still be described by the $PR_i = FR$ function.

The broken lines in Fig. 7 represent the switching performance of the two chimpanzees. The empirical curves fit the $PR_i = FR$ curve rather well. Thus, when the previously least efficient strategy ($PR_i = FR$) was made the most practical in terms of the number of reinforcements per session, the animals adjusted their schedule preference performance accordingly and switched from PR to FR at the equality point.

DISCUSSION

The results of these experiments seem to implicate the minimization of reinforcement cost as a principal determiner of preferences for particular response requirements in the type of forced choice situation used in Exp. 1. Moreover, the subjects appeared to be minimizing costs over large behavioral segments, rather than basing their preferences on a run-by-run evaluation of relative costs. When, as in Exp. 2, the PR reset contingency was elimi-
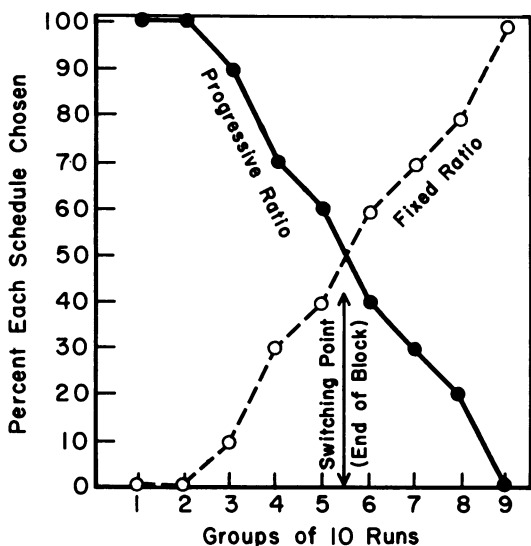

Fig. 6. An illustration of the method of determining the switching point in Exp. 2. The switching point was reached when the number of fixed-ratio and progressive-ratio selections were equal in any given successive group of 10 runs.
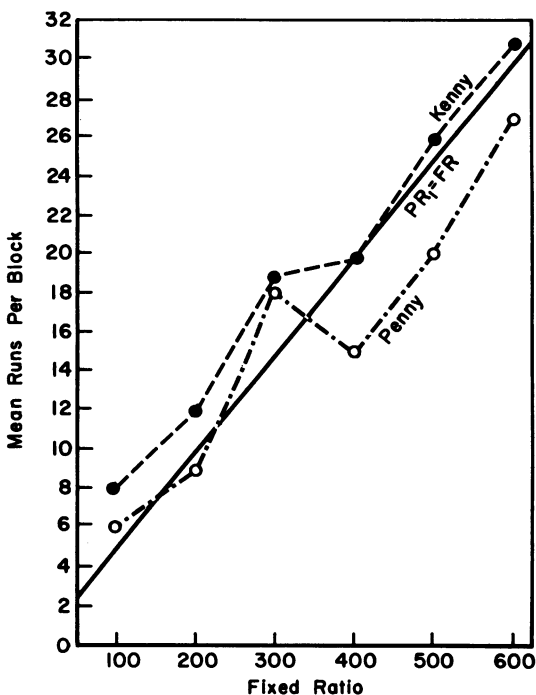

Fig. 7. The results of Exp. 2. The performance of each animal (broken lines) is plotted as a function of the fixed-ratio requirement. The data are compared to a theoretical switching curve (unbroken line) based on the "strategy" of matching the fixed and progressive-ratio requirements.

nated and their previous switching points resulted in very few reinforcements per session, the subjects responded by matching the individual PR requirement to the FR requirement even though this resulted in higher progressive ratios than in Exp. 1.

In his study of schedule preferences and schedule switching, Findley (1958) reported an experiment which at first appeared to support the results and conclusions reported here. In Findley's experiment, a pigeon's keypecking was reinforced on a PR schedule. The bird could reset the PR requirement to its minimum value by pecking a second key on a FR schedule. Thus, Findley's procedure differed from ours only in that the subject did not receive a primary reinforcement at the end of the FR run. The FR requirements used by Findley were 1, 20, 40, 80, and 100. The PR requirement increased by 100 responses after each reinforcement. Findley's data were presented in the form of representative cumulative records. We analyzed these records to determine the number of runs per block as a function of the FR requirement. The results are shown in Fig. 8-A as the unbroken line. The general trend of the data is similar to that shown in Fig. 3; *i.e.*, the number of runs per block increases as a function of the FR requirement. The curve for Findley's pigeon in Fig. 8-A does not show the tendency towards negative acceleration seen in the empirical curves in Fig. 3, but this may be due to the relatively low values of the FR requirement which Findley used. Figure 8-B describes the changes in reinforcement cost per block as the pigeon progressed through the PR-FR sequence. The lowest value on the abscissa is two; this is the lowest number of runs per block that is meaningful in Findley's experiment since the FR runs were not followed by primary reinforcement. The minimum value of each curve occurs at two runs per block. This is because the FR requirements are less than the PR increment. In the case of FR 100, which is equal to the PR increment, minimization of cost occurs at two and three runs per block. Thus, the curves indicate that in order to minimize reinforcement cost, the bird should have alternated FR and PR runs at all values of the FR requirement; *i.e.*, there should have only been two runs per block. Theoretical performance based on this strategy is shown as a broken line in Fig. 8-A.

Clearly, the switching behavior of Findley's pigeon was not determined by the principle of reinforcement cost minimization. This outcome appeared to be at variance with the conclusion that minimum reinforcement cost per block was a controlling variable for schedule preference in this type of situation. However, further consideration of the economics of Findley's experiment and the present one, suggested that the difference in procedure might be significant. In Exp. 1 reported here, each FR run was followed by a primary rein-
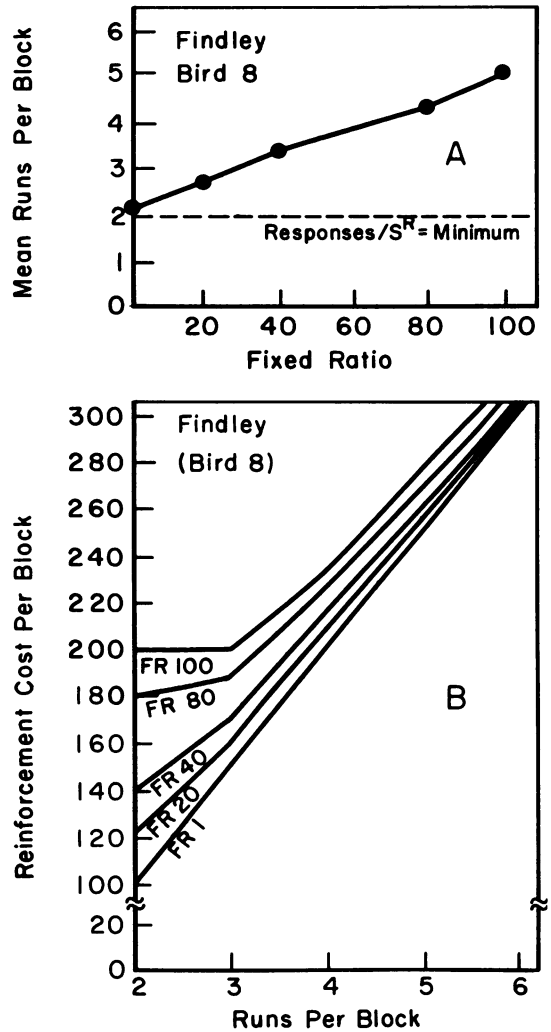

Fig. 8. A. Switching performance of Bird 8 (unbroken line) computed from Findley's (1958) data. The data are compared to the theoretical switching curve (broken line) based on minimization of reinforcement cost per block. B. Reinforcement cost per block as a function of number of runs per block at each value of the fixed-ratio requirement in Findley's (1958) experiment.

forcement. In Findley's experiment, each FR run had as its sole consequence the resetting of the PR requirement to its minimum value. Thus, in the present experiment, the number of runs and the number of primary reinforcements were the same; in Findley's experiment, the number of runs was always greater than the number of primary reinforcements. This suggests that three variables should be considered in the determination of reinforcement cost: the number of responses, the number of primary reinforcements, and the number of runs. We therefore calculated reinforcement cost per run (*i.e.*, reinforcement cost per block divided by the number of runs per block) for the parameters used in Exp. 1 and those of Findley's experiment. The variations in this quantity as a function of progression through the block are shown in Fig. 9. Part A of the figure describes changes in reinforcement cost per run in Exp. 1 and Part B describes the same relationships for Findley's situation.

The curves in Fig. 9-A were plotted by dividing the reinforcement cost per block at each point in the progression by the number of runs per block at that point. Thus, in the case of FR 40, a block of two runs (*i.e.*, two reinforcements) would have a reinforcement

cost per block of 30 (see Fig. 4). This cost, divided by the number of runs per block (two) results in a reinforcement cost per run of 15.

The curves in Fig. 9-B were also plotted by dividing the reinforcement cost per block by the number of runs per block. Thus, in the case of FR 40, a block of three runs (*i.e.*, only two reinforcements) would have a reinforcement cost per block of 170 (see Fig. 8-B). This cost, divided by the number of runs per block (three) results in a reinforcement cost per run of 57.

Fig. 10. Observed and theoretical values of reinforcement cost per run at each fixed-ratio requirement. A. Observed values in Exp. 1. B. Observed values in Findley's (1958) experiment. C. Theoretical values based on minimization of reinforcement cost, matching of the fixed-ratio and progressive-ratio requirements, and a constant number of runs per block.
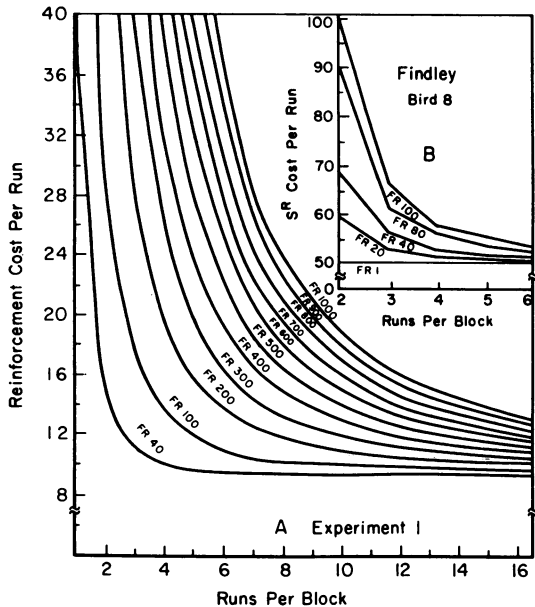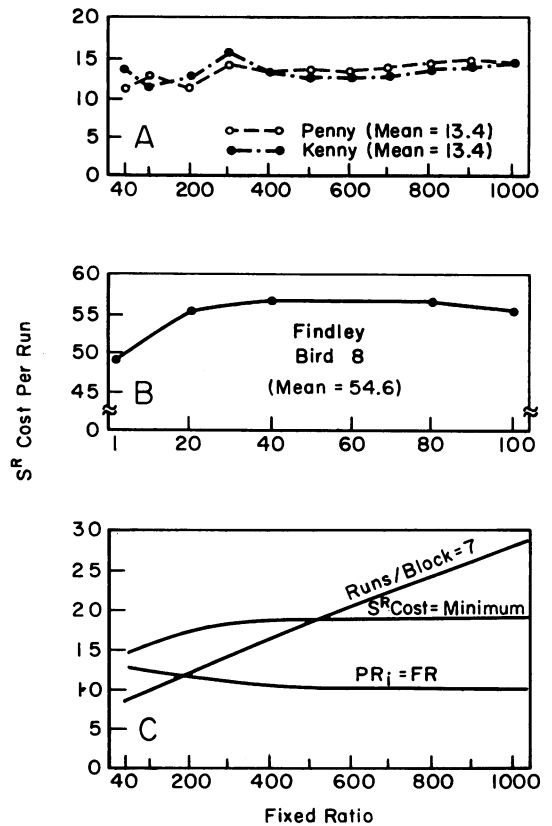

Fig. 9. Reinforcement cost per run as a function of the number of runs per block at each value of the fixed ratio in Exp. 1 (A) and in Findley's (1958) experiment (B). See text for definition of "reinforcement cost per run."

Figure 10-A presents the values of reinforcement cost per run obtained from the data of Penny and Kenny and Fig. 10-B presents the data obtained from Findley's Bird 8. In all three animals, the values of the curves appear to be relatively constant.

Figure 10-C indicates what the values of reinforcement cost per run would have looked like if the animals' performance in Exp. 1 had been accurately described by either of the two theoretical switching curves shown in Fig. 3. Although both of these "strategies" also result in constant values of reinforcement cost per run over much of the range of the FR requirements, the empirical values of reinforcement cost per run fall about midway between the two. Also plotted in Fig. 10-C is a curve which indicates how reinforcement cost per run would change as a function of the FR requirement if the number of runs per block remained invariant at seven runs. The three curves in Fig. 10-C were obtained from Fig. 9-A by reading on the ordinate the value of reinforcement cost per run at the point at which the appropriate number of runs per block crossed each FR curve.

Since reinforcement cost per run remains remarkably stable in spite of extreme variation in the FR requirement and a changing number of runs per block, this measure could serve as a predictor of switching performance. Ideally, one would merely have to determine the reinforcement cost per run for one value of the FR requirement in order to generate the entire curve of switching performance. This could be done, using Fig. 9, by drawing a line parallel to the abscissa at the average empirical value of reinforcement cost per run for each animal and reading off the number of runs per block at the point at which this line crosses each FR curve. As a test of the predictive power of reinforcement cost per run, the mean values of this measure for Penny, Kenny, and Findley's Bird 8 were used to generate theoretical switching performance curves based on the functions in Fig. 9. These theoretical curves are shown in Fig. 11. Part A shows the data obtained in Exp. 1. compared to a theoretical curve based on a value of reinforcement cost per run of 13.4 which was the mean value for each of the two chimpanzees. This theoretical curve seems to be a close fit to the empirical curves. Figure 11-B shows a similar theoretical curve compared to the empirical curve for Findley's Bird 8. Here too, the theoretical curve fits the observed performance rather well.

Although the constancy of reinforcement cost per run seems to have considerable power in predicting preferences between fixed- and
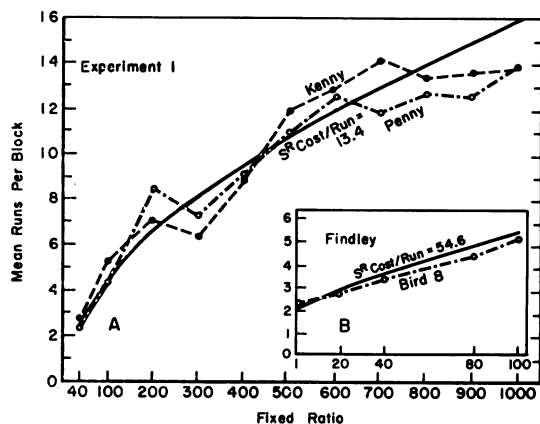

Fig. 11. The data of Exp. 1 (A) and of Findley's (1958) experiment (B) have each been compared with a theoretical switching curve based on the maintenance of a constant value of reinforcement cost per run. In each case, the empirical curves are shown as broken lines and the theoretical curves as unbroken lines.

progressive-ratio schedules, it is not at all obvious as to what aspect of the situation the animals discriminated which could have resulted in those behavioral adjustments which maintained the constancy. On the other hand, it was not necessary for the animals to have actually discriminated the reinforcement cost per run any more than a baseball player is required to know the acceleration of gravity in order to adjust his behavior in accordance with the trajectory of a falling baseball. Just as the baseball player responds to stimulus changes which are correlated with the trajectory of the ball, the animals may also be responding to changes in some stimulus which correlates reliably with reinforcement cost per run. Revusky (1963) observed that when relative response rates and relative reinforcement rates are the same on two concurrent variable-interval schedules, reinforcement costs must also be the same. This suggests that the animals in the present experiment and Findley's Bird 8 may have been discriminating some aspect of the relative reinforcement rate which was correlated with reinforcement cost per run. Revusky's observation might therefore form the basis for a single indicator which would be effective in predicting preferences among both ratio and interval schedules.

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