

INTERMITTENT REINFORCEMENT OF OPERANT BEHAVIOR IN CHILDREN¹

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Current research dealing with the effects of various schedules on free-operant behavior in lower organisms is aided greatly by a large literature of techniques and data. Unfortunately, only a limited literature of this sort is available to aid investigators of operant behavior in children. The purpose of this paper is to present some techniques and data which may be of use to others working in this area.

PROCEDURE

Subjects

Approximately 200 children varying from four to eight years participated as subjects. Attempts were made to use children three years and younger, but for the most part these were unsuccessful because the children refused to remain alone in the experimental cubicles for more than a few minutes. Pre-elementary school children were obtained through local kindergartens and nursery schools. Older children were obtained through public schools. In all instances, permission was obtained from parents as well as school officials before a child was used, and all subjects participated on a volunteer basis.

Apparatus

Three small rooms, each 9 feet by 10 feet, were used as experimental cubicles. Each contained a console which housed a Gerbrands Universal Feeder, a 35-millimeter automatic projector, and various lights used as discriminative stimuli. Mounted on the face of the console before the subject was a 16-inch-by-16-inch translucent screen on which discriminative stimuli or reinforcing pictures were projected. The subjects operated Lindsley manipulanda or enclosed telegraph keys used as manipulanda. Reinforcers, e.g., trinkets and pennies, were delivered through a small aperture in the face of the console into a tray.

The electrical circuitry used to schedule reinforcement and record responding was similar to that described by Ferster and Skinner (1957). Therefore, no description of it is given here. All circuit changes, programming, and recording were carried out in a separate room away from the experimental cubicles.

Instructions

The instructions were both demonstrational and verbal. They were designed to acquaint the subject with the manipulandum, the nature of the reinforcers, and the fact that reinforcement did not always follow an operation of the manipulandum. All of this was accomplished in a 1-to-2-minute period.

Specifically, at the beginning of the first session, each child was shown the manipulandum and told to operate it. The first response always produced a reinforcement, i.e., a trinket or penny was delivered, a loud buzzer sounded, and the yellow or green light already projected on the translucent screen was changed to a

¹ This research was supported in part by USPHS Grant M-2007.

red one. The red light remained on and the buzzer continued to sound for approximately 2 seconds. At the end of this time, the magazine stimuli were terminated and the original stimulus light was returned. The child was then asked to operate the manipulandum again. This time, however, no reinforcement occurred, and the child was told that sometimes when he operated the manipulandum he would get a "prize" and sometimes he would not. He was further instructed that in order to get a prize, he must operate the manipulandum and that he would get no prize if he did not. The experimenter then informed the child that he was going to leave and that during his absence the child could win some more prizes if he wished. The experimenter then left the room, and closed but did not lock the door. During subsequent sessions, such instructions were unnecessary; the child usually went directly to his cubicle, closed the door, and started working. The duration of the experimental sessions was approximately 25 minutes.

Reinforcers

Trinkets, pennies, and projected 35-millimeter Kodachrome transparencies were used as reinforcers. The trinkets were small plastic and metal charms and tokens purchased from two chewing-gum-machine suppliers.² While trinkets alone were usually adequate for pre-school children, they were not for older children, and pennies were therefore substituted. Sometimes combinations of pennies and trinkets were used if a child manifested an interest in both.

Another reinforcing procedure which was used with fixed-interval schedules was the projection of 35-millimeter Kodachrome transparencies. These were never used alone but in conjunction with other reinforcers, and they seemed to produce the greatest effect if they were projected while the child worked and were changed during reinforcement. A more detailed description of this procedure is given later in the article.

Schedules

Three schedules of reinforcement were used: fixed ratios, fixed intervals, and variable intervals. Only a few values of each schedule were used, and for the most part these were small. Specifically, these were: FR 5, 10, 25, 50, 60, 75, 90, 100, and 150; FI 0.5 (minutes), 1, 1.5, 2, and 3; and VI 0.5 and 1. Extensive and prolonged use of small ratios and intervals was avoided because of satiation effects. Large ratios and especially large intervals (2 minutes and larger) were avoided because the children found them aversive.

PERFORMANCE ON FIXED-RATIO SCHEDULES

Initiating Reinforcement on FR Schedules

Little difficulty seems to be encountered in initiating a particular schedule of intermittent reinforcement with lower animals. With fixed ratios, this ordinarily has been accomplished by starting an animal on continuous reinforcement and then shifting him to small fixed ratios which are later increased in size. Changes such as these were found to be more difficult to effect in children. Continuous reinforce-

²These were the Penny King Co., 2538 Mission Street, Pittsburgh, Pa., and Plastic Processes Incorporated, 83 House Avenue, Freeport, N. Y.

ment or prolonged reinforcement on small FR's frequently produced rapid deceleration of the over-all rate within that particular session. In addition, after two or three sessions on such schedules, children came to possess all of the different sorts of trinkets available. When this occurred, that is, when "no new prizes" could be won, the reinforcing effect of the trinkets greatly diminished. On the other hand, beginning a child on a ratio which was too large frequently had equally unfortunate effects. Research therefore was conducted to determine useful procedures for beginning children on fixed-ratio schedules.

Use of Small FR's During First Session. In the first procedure studied, small FR's (5, 10, 15, or 20) were used during the first session, and the size of the ratio was then increased during subsequent sessions. Figure 1 contains the first-session rec-

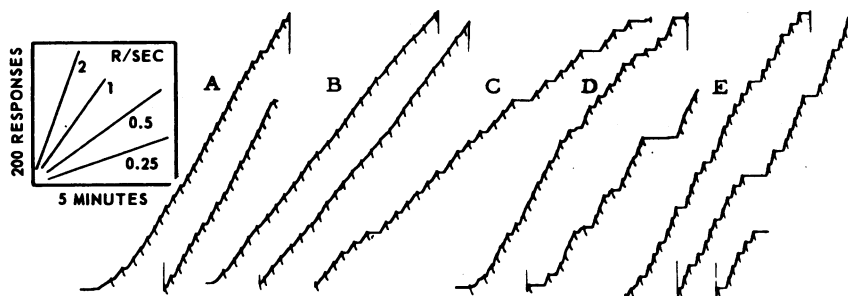


Fig. 1. First-session records of five children on FR 15.

ords of five children on FR 15. Although they differ in over-all as well as running rate, all are ratio-like. What is of major importance is that three of the records (1-C, 1-D, and 1-E) show declines in over-all rate as the session progresses. For the most part, these declines are produced by increases in pausing after reinforcement. Only in 1-D are there instances of negative curvature and intervening rates. Decelerations such as these are typical of the records of children on fixed ratios of 15 or less. In general, they resemble those reported by Ferster and Skinner (1957) for pigeons whose body weights had been allowed to increase well above the 80 per cent level.

Increasing Size of FR During First Session. A second and somewhat more successful first-session procedure entailed starting a child on an FR 15 and then increasing the size of his ratio within that session. Figure 2 shows the first-session records of four children given such training. With the first subject (2-A), nine reinforcements were given at FR 15; five at FR 20; eight at FR 25, eight at FR 35; five at FR 40; four at FR 45; and 10 at FR 50. The ratio was increased more rapidly for the second subject (2-B). After 10 reinforcements on FR 15, it was increased first to 25, then to 45, and finally to 60. Essentially the same procedure was followed for a third subject (2-C). The final ratio in this case was 70.

In all three cases, surprisingly strong FR control was developed. Moreover, no instances of deceleration due to the rapid accumulation of trinkets was observed. The few instances of pausing which were observed when this procedure was used were produced by a too rapid increase in the size of the ratio. An example of this

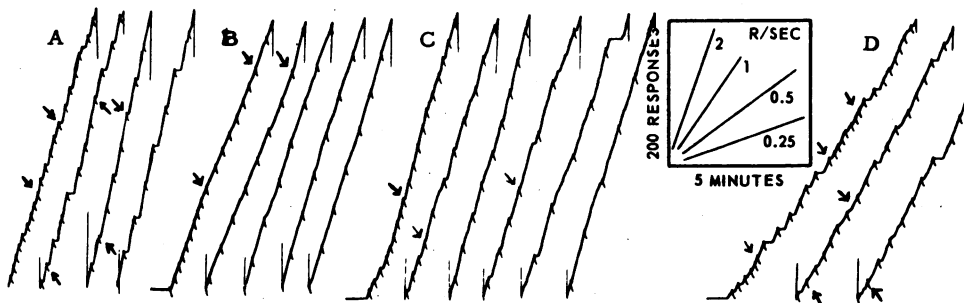


Fig. 2. Effect of increasing size of ratio during first session.

is in Record 2-D. This subject was begun on an FR 15, and after six reinforcements shifted to FR 25. After seven reinforcements at this value the ratio was returned to 15, in order to reduce the pausing. It was later increased to 20, 25, 30, and finally to 35. Although FR control was never strong during the first session, it was during the following session, and the ratio was increased successfully to 60.

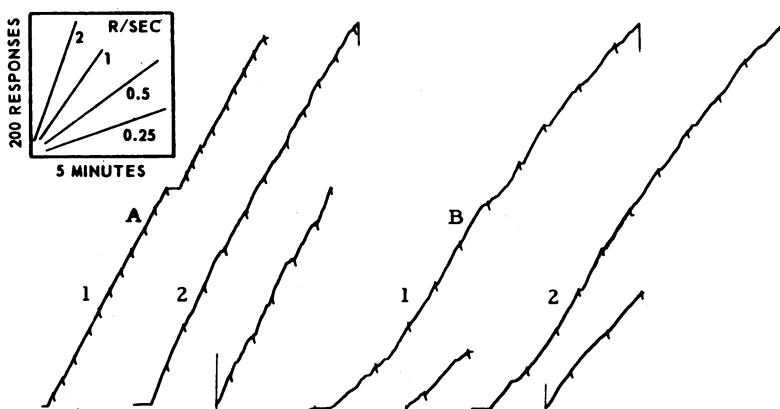


Fig. 3. Differential effect of using FR 25 and FR 60 during first session.

Use of Large FR's During First Session. Attempts were made to begin subjects on even larger ratios. In Fig. 3 are the records of the first and second sessions of two subjects. One subject was begun on FR 25 and then shifted to FR 60 at the beginning of the following session (3-A-1 and 3-A-2). The other subject was begun and maintained on FR 60 throughout both sessions (3-B-1 and 3-B-2). First-session records (3-A-1 and 3-B-1) indicate that the FR 25 produced responding which was much more ratio-like. The rate was higher and there was less grain, pausing after reinforcement, and negative curvature. Note should be taken of the acceleration of rate during the first reinforcements of the subject on FR 60. In many ways, this record resembles initial records of those subjects begun on FI 1. Subjects begun on FR 25 rarely if ever showed this initial acceleration.

The records of the second sessions indicate essentially the same thing. A temporary drop in rate occurred when the FR 25 was changed to FR 60 (3-A-2). Neverthe-

less, this rate was higher than the second-session rate of the subject begun on FR 60 (3-B-2), and the performance was generally superior in regard to such characteristics as negative curvature and intermediate rates. The four records of Fig. 4 illustrate the development of FR 60 control. They are the first four sessions of a child

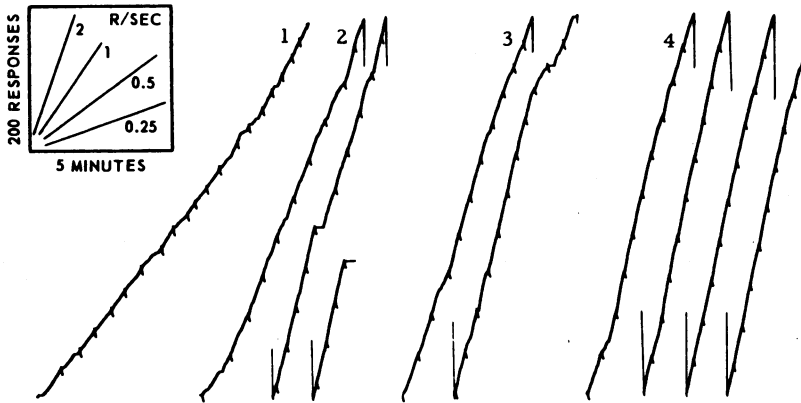


Fig. 4. Development of FR 60 control.

begun on FR 25 (4-1) and shifted to FR 60 at the beginning of the second session (4-2). On the fourth session (4-4), except for the first excursion the record is grainless and has a high rate with little or no curvature or pausing. The procedure of placing a subject on an FR 25 for one session and then shifting him to an FR 60 was successful in producing strong FR 60 control with most subjects. This was true even though they did not give stable FR 25 data before the shift was made. Good control was never developed for those subjects begun and maintained on FR 60.

Decline in Reinforcing Effect of Trinkets

Effect of Changing Trinkets. The records of Fig. 5 have been included to illustrate the decline in reinforcing effect of the trinkets after prolonged use. Record 5-1 is that of the seventh session of a child who was begun on an FR 25 and then shifted to an FR 60 at the beginning of his second session. The record contains several long pauses but is relatively free from grain and negative curvature. In general, it is very ratio-like. Records 5-2, 5-3, 5-4, and 5-5 are of his eighth, ninth, tenth, and eleventh sessions, each separated by a 1-week intersession interval. They indicate that so much progressive deterioration in performance has taken place that Records 5-4 and 5-5 are no longer ratio-like. The next record (5-6) was obtained after a 3-week intersession interval. Except for a reduction in the amount of time occupied by intermediate rates, little effect can be seen. The following week new trinkets, that is, trinkets unlike those previously employed, were used (Record 5-7). Although the record is far from grainless and there are some instances of split or interrupted ratios, almost no traces of intermediate rates can be found, over-all rate is higher, and performance is much more ratio-like. Most of the pauses in this record were produced by competing behavior, namely, the child's leaving his cubicle to show the

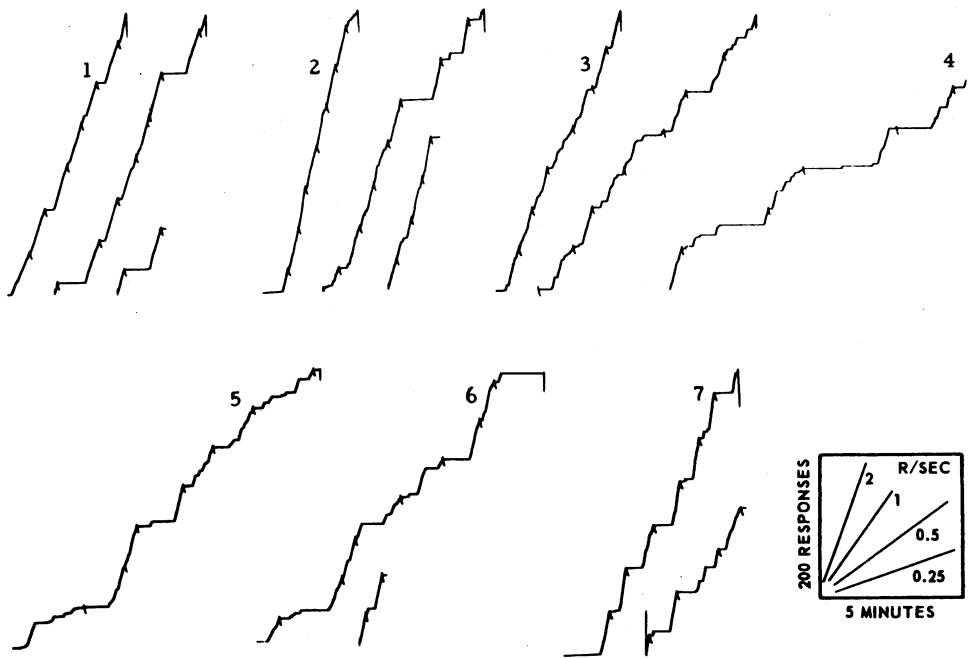


Fig. 5. Effect of decline in reinforcing effect of trinkets on FR 60 performance.

experimenter his "new prizes." If the recorder had been stopped during these periods, the records would have indicated an even greater change.

The initial record of the previous subject, although ratio-like, was by no means as stable as those of other subjects. This raises the question: would the records of those subjects whose responding was more under the control of the schedule reflect the same sorts of deteriorative changes? The three records of Fig. 6 have been in-

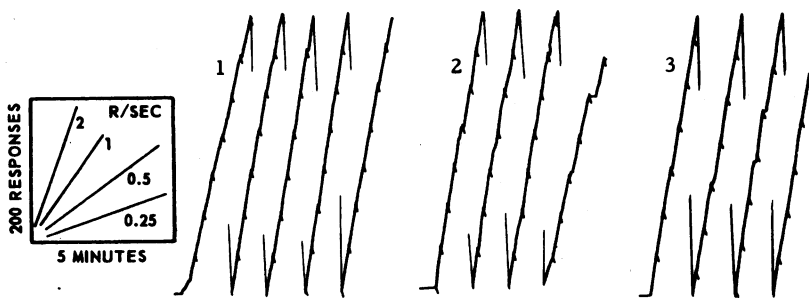


Fig. 6. Effect of decline in reinforcing effect of trinkets on performance where FR control is strong.

cluded to answer this question. The first (6-1) is the record of the seventh session of a child on FR 60. It is grainless, free from pausing and curvature, and has a high rate. By the tenth session (6-2), declining running rate and instances of grain, negative curvature, and pausing can be seen in the record. On the following session, 1

week later (6-3), new types of trinkets were used as reinforcers. This resulted in a higher rate and the almost complete elimination of grain, pausing, and negative curvature. Thus, even lawful ratio behavior—that almost completely under the control of the schedule—reflected the decline in the reinforcing value of the trinkets as the number of sessions was increased. The behavioral effect of this decline was not so great in this case, however, as it was in the previous one.

Effect of Increasing Intersession Interval. Although the subject depicted in Fig. 5 was not influenced by increases in intersession intervals, other subjects were. This is illustrated in the records of Fig. 7. Record 7-1 (the seventh session) has a high running rate and little or no grain, curvature, or pausing. Performance during suc-

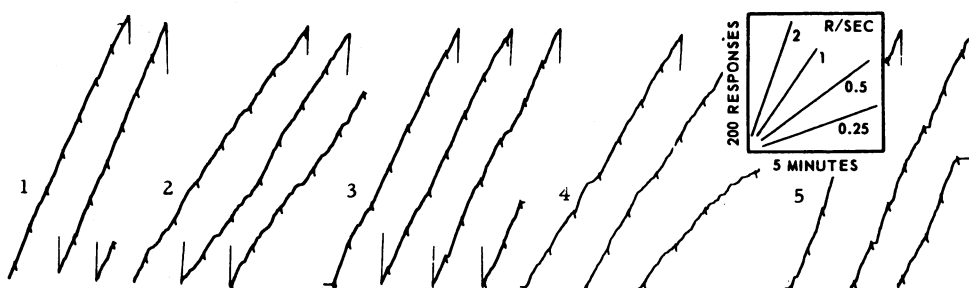


Fig. 7. Effect of increasing intersession interval.

ceeding sessions (with intersession intervals of 1 week), however, showed progressive disintegration—increasing grain, intervening rates, and negative curvature. This can be seen in the record of the ninth session (7-2). The intersession interval of the tenth session was then increased to 2 weeks (7-3). This resulted in a higher rate and a reduction of grain. The eleventh session was conducted again after an intersession interval of only 1 week (7-4), and many of the deteriorative characteristics reappeared. A 2-week intersession interval was then allowed to elapse before the twelfth session (7-5). The rate again went up, although much of the grain and negative curvature persisted. Thus, increasing the length of the intersession interval improved ratio performance by increasing the rate and reducing grain and negative curvature; its effects were much less pronounced, however, than those produced by changing reinforcers.

The progressive deterioration over sessions seems much like that reported by Ferster and Skinner for pigeons receiving insufficient reinforcement. The intersession changes reported here differ from the changes reported earlier. Those occurred within one session and were contingent on the use of small FR's. In addition, the previously discussed decline in over-all rate was for the most part due to an increase in pausing; responding, when it occurred, was at a high constant rate. Here, the decline was due only in part to increased pausing; negative curvature, intermediate rates, and split or interrupted ratios played more significant roles. These deteriorative changes argue strongly against the use of small ratios early in training if a limited number of different trinket types is available and if many future sessions have been planned for the same subject.

Reducing Size of Ratio. Another manipulation designed to reduce the irregularities produced by the decline in reinforcing effect of the trinkets was reducing the size of the ratio. Figure 8 contains the records of two subjects shifted from FR 90 to FR 25. After 10 reinforcements, almost all pausing, negative curvature, etc., was eliminated and the running rate was increased. These data suggest that even though the trinkets had lost so much reinforcing effect that they were unable to maintain FR's of 90, they were still strong enough to maintain smaller ratios of 25.

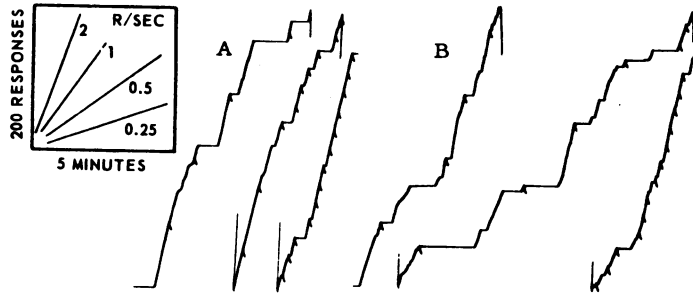


Fig. 8. Reduction of FR 90 to FR 25.

The records of Fig. 8 perhaps suggest that increases to large ratios, e.g., FR 90, could not be made without deterioration of performance. Such was not the case, however, if the trinkets had a high reinforcing effect and if the subject had experienced sufficient sessions for the schedule to control his performance. Records 9-A-1 and 9-A-2 are included to illustrate this. The first (9-A-1) is the record of the fifth session of a subject on FR 60. The rate is high, and there is very little pausing and curvature. The second (9-A-2) is the record of his next session; at the beginning of this, he was shifted to FR 90. The shift was effected without any increase in pausing and curvature; in fact, the running rate was actually increased.

Record 9-B illustrates the effect of increasing the size of the ratio too rapidly, that is, before the schedule has come to exercise strong control over performance. In this case, after three reinforcements had been given at FR 25, the ratio was increased to 50, at which value 15 reinforcements were given. Because the rate was high and the record was free of pausing and curvature, the ratio was further increased to 100. By the second reinforcement at FR 100 the running rate had begun

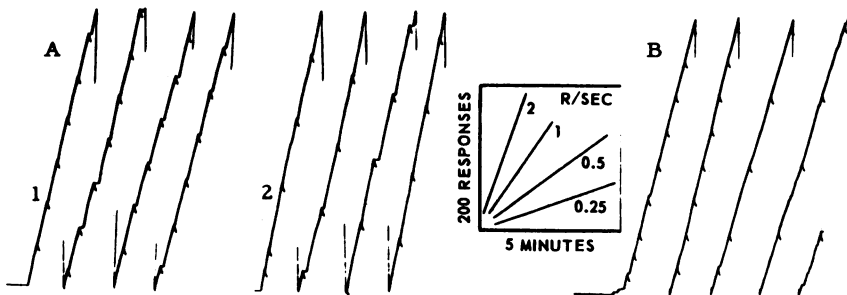


Fig. 9. Effect of increasing size of ratio.

to decrease and by the fifth, curvature had become detectable. The size of the ratio was reduced during the following session. Had it been allowed to continue, however, much more serious deterioration undoubtedly would have taken place.

Strength of FR Control

The earlier records concerned with the initial use of fixed-ratio schedules suggested that these schedules exercised powerful control over children's responding in this situation. Data reported subsequent to those could conceivably give the impression that the fixed-ratio's control was transitory, and behavior which previously had been under the control of this schedule was soon replaced by random responding. This was not the case. Only when the trinkets lost their reinforcing effect or when the size of ratios was increased too rapidly was the control weakened.

Shift from FI to FR. The sensitivity of children to the fixed-ratio schedule and its control over behavior can be illustrated in a second way, namely, by shifting from an interval schedule to a fixed ratio. Record 10-1 is a record of a 7-year-old child being maintained on a fixed-interval schedule of 1.5 minutes (FI 1.5). At each reinforcement he received a penny and a trinket; he heard the sound of a buzzer; and

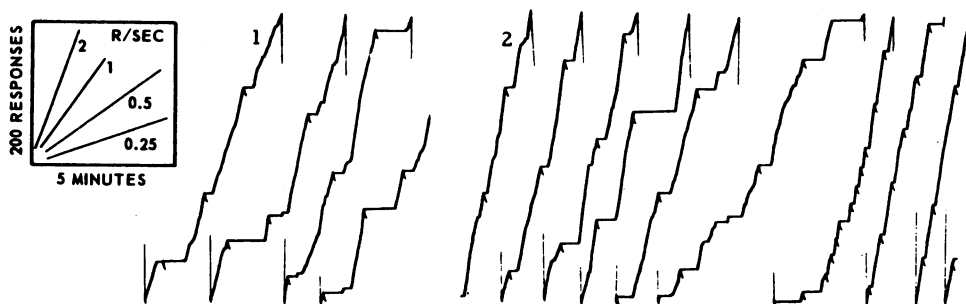


Fig. 10. Shift from FI 1.5 to FR 150.

the picture which had been projected on a translucent screen before him was replaced by a new one. (This particular reinforcement procedure will be discussed in more detail when fixed-interval schedules are considered.) The schedule has come to control his behavior. There is a pause after each reinforcement; after the pause, rate of responding increases until a terminal rate is reached, this usually being held until the next reinforcement. The transition from pausing to terminal rate is on some occasions gradual and on others abrupt. Deviations of various kinds are observable. These include negative acceleration, multiple runs, and knees. The general course of the record, however, is apparent at all times.

At the beginning of the following session, an FR 150 was substituted for the fixed-interval schedule. The first six excursions of the second record (10-2) depict his responding on this schedule. Performance during the first five excursions is almost indistinguishable from the earlier behavior on the FI. After 13 reinforcements, however, considerable negative acceleration and grain developed. After 16 reinforcements on FR 150 the ratio was dropped to 25, and almost immediately responding became ratio-like. After eight reinforcements on FR 25 the ratio was increased to 75, and after 10 reinforcements at this value it was again put at 150.

Although only two reinforcements were given at this value, enough of the record is available to indicate a marked difference between the FR 150 performance at this time and that obtained with FR 150 earlier in the session.

Shift from VI to FR. The records of Fig. 11 also illustrate the development of FR control. In this case the shift is made from a variable interval of 1 minute (VI 1) to an FR 25. The first (11-1) is a record of performance on a VI 1; at the beginning of the next session (11-2) the schedule was changed to an FR 25. It can be seen that the FR contingencies did not begin to control responding until about halfway through the third session (11-3). These records clearly illustrate the point made by

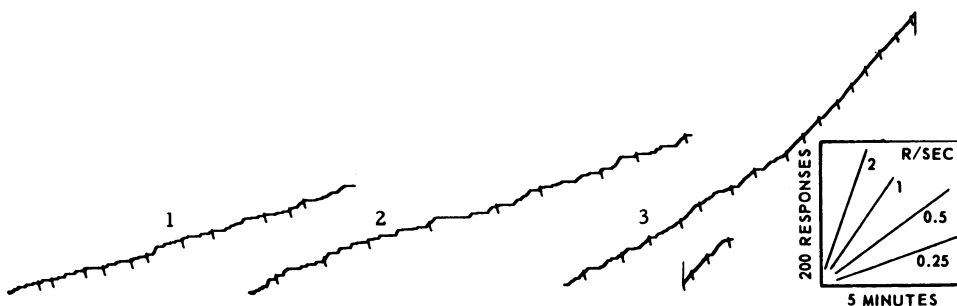


Fig. 11. Shift from VI 1 to FR 25.

Ferster and Skinner that the schedule operates in conjunction with the behavior which the organism brings to the experimental situation. Shifting from an FI 1.5 to an FR 150 directly did not allow the FR contingencies to gain control of behavior. Very rapid and potent control was developed, however, as soon as the ratio was dropped to a low value and then increased. Essentially the same thing was true for the shift from the VI 1 to the FR 25. Had a ratio smaller than 25 been used, ratio control would have been developed much sooner.

Summary of Performance on Fixed-ratio Schedules

1. Responding which was reinforced intermittently with trinkets on FR schedules closely resembled that reported for other organisms reinforced with homeostatic rewards.

2. First-session FR schedules of 20 or less frequently produced a deceleration of over-all rate (within that session) which was characterized principally by increases in length of pausing after reinforcement. When subjects responded, it was usually at the terminal rate. This was viewed as being similar to the satiation effects reported by Ferster and Skinner for other organisms.

3. An argument against the continued use of small ratios was the reduction in reinforcing effect of the trinkets as large numbers of them were accumulated. The performance of all subjects underwent deterioration as the number of sessions was increased. This deterioration was characterized by increased instances of pausing, intermediate rates, negative curvature, and grain. In general, the stronger the FR control the less marked was the deterioration. Substitution of new trinkets, dou-

bling the number given at reinforcement, increasing the intersession interval, as well as reducing the size of the ratio were found to ameliorate the deteriorative changes. The deterioration of FR performance in the present experimental context seemed closely akin to those changes reported by Ferster and Skinner for pigeons which were given insufficient reinforcement.

4. Although prolonged use of small ratios resulted in satiation and reduction of reinforcing effect of the trinkets, initial use of ratios which were too large had equally unfortunate effects. Subjects begun on ratios as large as 60 failed to show ratio-like behavior even after as many as 17 sessions.

5. Fixed ratios could be increased easily to 90 or 100 if sufficient control was developed with smaller ratios and if the reinforcing effect of the trinkets had not been reduced.

6. Fixed-ratio schedules in general were found to exercise considerable control over performance. Almost all children showed great sensitivity to them. When interval schedules were changed to ratios, most children showed changes in rate pattern within a short period of time. An immediate change from a particular FI to a particular FR (e.g., FI 1.5 to FR 150), however, was not always found to produce ratio-like behavior. It was necessary first to reduce the size of the ratio and then gradually increase it to the desired size. Fixed-ratio schedules thus were found to operate in conjunction with the behavior which subjects brought to the experimental context.

PERFORMANCE ON FIXED-INTERVAL SCHEDULES

Initiating Reinforcement on FI Schedules

Many of the problems encountered in beginning children on fixed-ratio schedules were encountered in initiating reinforcement on fixed-interval schedules. Again, research was conducted to determine the differential effects of various initial procedures.

Continued Use of FI 1 During First Session. The records of Fig. 12 depict first-session performances of subjects begun on fixed intervals of 1 minute (FI 1). Three of the records (12-A, 12-B, 12-C) show a gradual acceleration of rate which usually extended over the first five or six reinforcements. In this respect, these records resemble those of the subjects begun on FR 60. With the subjects on FR 60's, however, the duration of the acceleration was much shorter, lasting for only one or two reinforcements.

The schedules began controlling the behavior of three subjects very quickly. Thus, in Records 12-B, 12-C, and 12-E pauses after reinforcement and acceleration to a terminal rate developed after six to eight reinforcements. The change from pausing to responding at the terminal rate was abrupt rather than gradual in many instances. In addition, a number of deviations and irregularities are superimposed on this general pattern. Nevertheless, these records resemble many of the records reported for other organisms on FI schedules.

Record 12-D is representative of the few subjects who showed little or no initial acceleration of over-all rate. The final record (12-F) is that of a subject who responded at a very low rate during the initial session on FI 1. Approximately 25 per cent of the subjects begun on FI 1's produced such initial records.

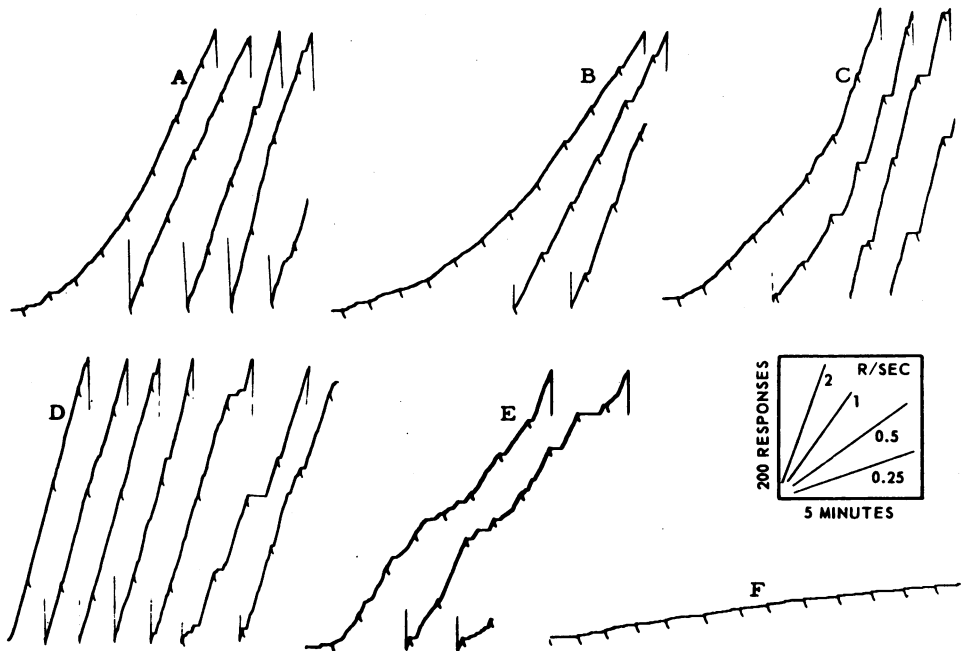


Fig. 12. First-session records of six children on FI 1.

VI 0.5 Shifted to FI 1 During First Session. In order to reduce the number of subjects yielding low-rate records of the type depicted in Record 12-F, additional subjects were begun on other schedules and then shifted to FI 1. In Fig. 13 are records of three different children given seven to nine reinforcements on a variable-interval schedule of 0.5 minute (VI 0.5) and then shifted to FI 1. For two subjects (13-A and 13-C), pausing after reinforcement soon developed in much the same way as it did for those subjects begun on FI 1. Pausing did not develop during the initial session of the third subject (13-B), although it did later. No instances of low rates of responding were found when small VI's were used prior to the FI 1. This procedure also greatly reduced the initial acceleration of over-all rate.

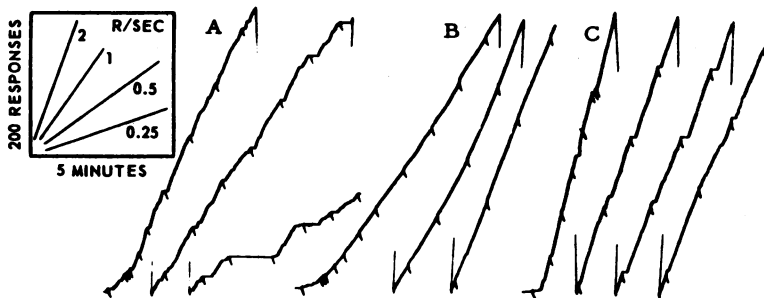


Fig. 13. Shift from VI 0.5 to FI 1.

FI 0.5 Shifted to FI 1 at Later Session. Other subjects were begun on FI 0.5 and then shifted to FI 1. Figure 14 contains the records of a subject given two sessions

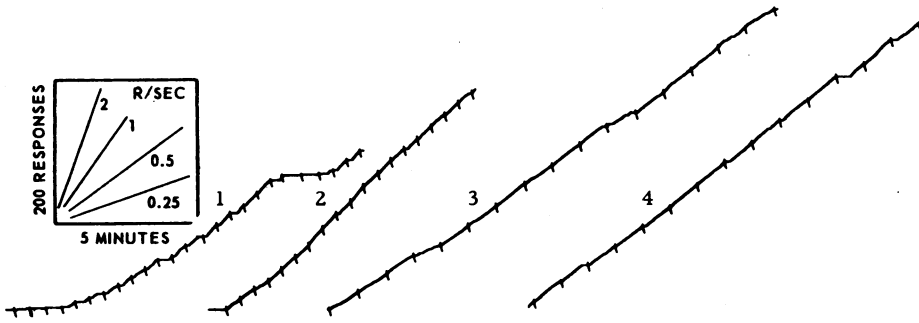


Fig. 14. Shift from FI 0.5 to FI 1.

on FI 0.5 and then shifted to FI 1 at the beginning of the third session. After five reinforcements of the first session on FI 0.5, this subject began pausing after reinforcement and then accelerating to a terminal rate (14-1). During the following session, however, his rate of responding was almost constant (14-2). Moreover, not until the second session on FI 1 (14-4) did this subject begin to pause after reinforcement.

FR Shifted to FI at Later Session. Subjects also were begun on small ratios before being shifted to FI 1. In Fig. 15 are the records of a subject who was reinforced on an FR 25 during her first session (15-A-1), and then shifted to an FI 1 at the beginning of her second (15-A-2). This subject developed a very high constant rate on FI 1, which continued for 10 sessions. Combinations of schedules also were used

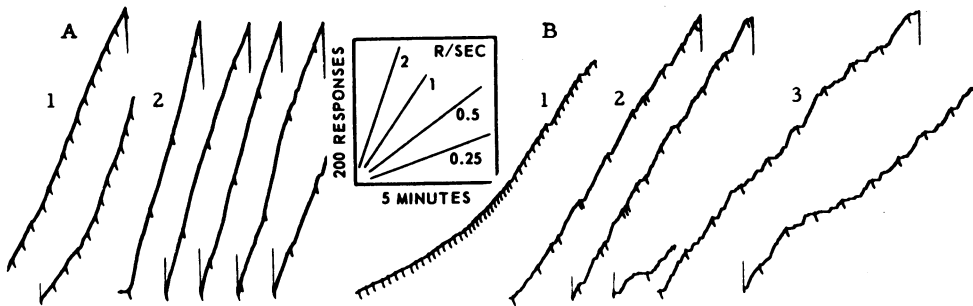


Fig. 15. Shift from FR 25 to FI 1 and from FR 5 and 10 to VI 0.5 to FI 1.

prior to beginning the FI 1. Figure 15 also contains the records of a child given both FR and VI experience before being placed on an FI 1. During his first session (15-B-1) the child was given 33 reinforcements on an FR 5 and then shifted to FR 10, at which value he received 17 additional reinforcements. On his second session, he was shifted to VI 0.5 (15-B-2); and on his third, to an FI 1 (15-B-3). This subject paused in some instances after reinforcement while on the VI 0.5, although this was not a consistent characteristic. He quickly developed the pause, however, when placed on the FI 1, and his responding soon took on FI-like characteristics, although in many instances he responded in ratio-like bursts. The latter had the effect of making the record grainy.

Performance after 10 Sessions on FI Schedules

Another question which suggested itself is what sort of similarity or diversity of records would be obtained from subjects who had been exposed to FI schedules for a large number of sessions. Figure 16 contains the records of five different subjects, all of whom had been on FI schedules for at least 10 sessions. Record 16-A is that of a subject on FI 1. For the most part, he paused after reinforcement; only in four out of 24 possible instances did he fail to do so. Irregularities, however, conceal almost all traces of the FI scallop. There are instances of multiple runs, knees or perhaps compensatory runs, and one instance of a second-order effect. The most prominent irregularity is the negative acceleration or failure to sustain the terminal rate as the session advanced. The best explanation for this seems to be the previously discussed decline in reinforcing effect of the trinkets. This subject had performed less irregularly prior to this session. Almost all subjects showed the same sort of change.

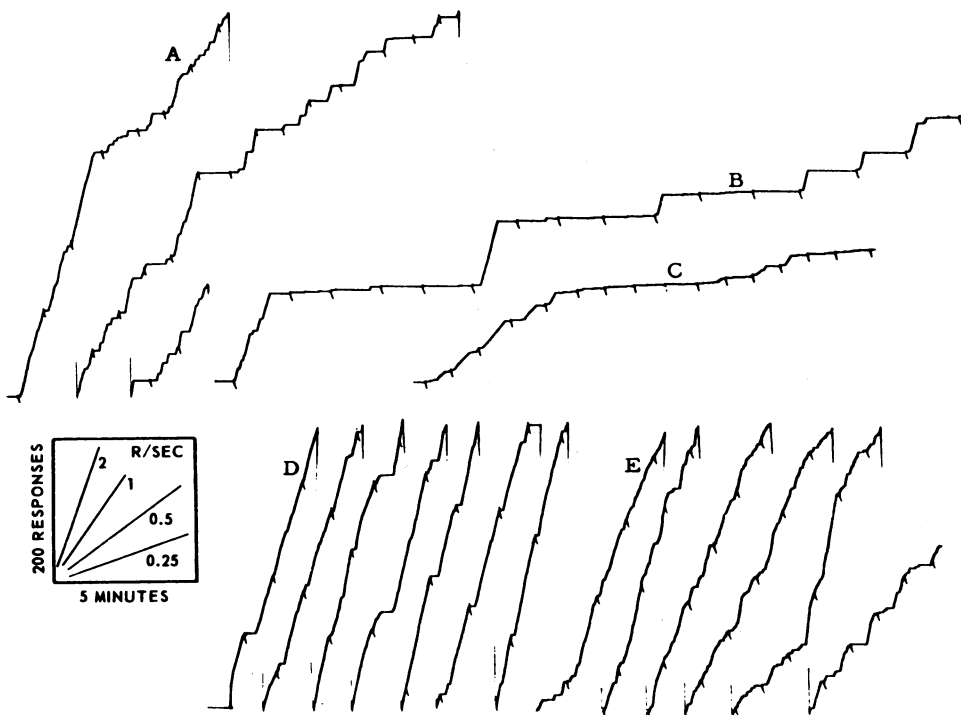


Fig. 16. Performances of five children after at least 10 sessions on FI schedules.

Records 16-B and 16-C represent the final performance of approximately 30 per cent of the children on FI schedules. Both of these subjects had responded at higher rates but currently were responding only two or three times during an interval. The subject depicted in Record 16-A conceivably might have come to respond in this manner if his training had been continued long enough. The low rate of responding seems to be due to a combination of the temporal discrimination pro-

duced by the FI schedule and the low reinforcing effect of the trinkets. Record 16-B is especially interesting in that occasionally a high rate of responding, which is not maintained, occurs soon after reinforcement. The explanation suggested by Ferster and Skinner for second-order effects seems most appropriate here. For example, after several instances of reinforcement at a low rate and a small number of responses (low count), the situation after reinforcement becomes more rather than less favorable, and thus responding begins very soon thereafter. The major difference between this record and those which they present is that here the high rate of responding is not maintained.

The subject depicted in 16-D worked at a high rate. His record contained many linear segments and instances of running-through reinforcement. A small number of subjects either worked at a high constant rate or responded randomly. Almost all subjects, however, showed some instances of the FI acceleratory pattern. Record 16-E is illustrative of this. This subject on an FI 1 responded at an irregular rate for almost four and one-half excursions, and then gave six consecutive scallops.

Instability of FI Performance

Several other representative records have been included to illustrate further the instability of performance maintained on FI schedules. The records of Fig. 17 are of the first three sessions of a subject begun and maintained on an FI 1. These records clearly illustrate the development of second-order effects superimposed on fairly typical FI responding. Not all subjects on FI's showed this type of deviation. Some subjects showed them only during a single session. This subject showed them during both his second and third (17-2 and 17-1).

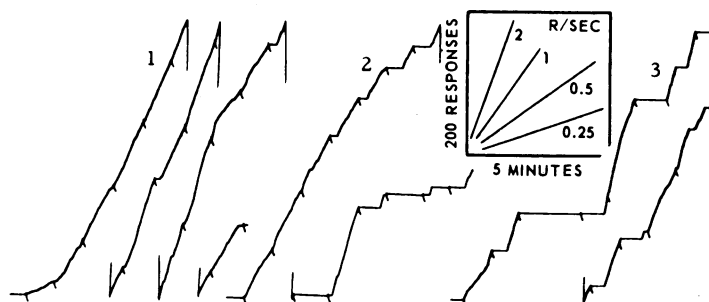


Fig. 17. Second-order effects.

The records of Fig. 18 illustrate the transitory characteristic of behavior maintained on FI schedules. They are the first three sessions of a child begun on VI 0.5 and then shifted to FI 1. In this case, the switch was made after the fifth reinforcement of the first session (18-1). During the first session, pausing appeared after nine or ten reinforcements. During the second session (18-2), almost consistent patterns of pausing and accelerating were developed; these persisted for nine consecutive reinforcements. This pattern was then replaced by a fairly high but irregular rate of responding. The record of the next session (18-3) shows a continuation of the same fairly high rate but with some reduction of grain. The acceleratory pattern

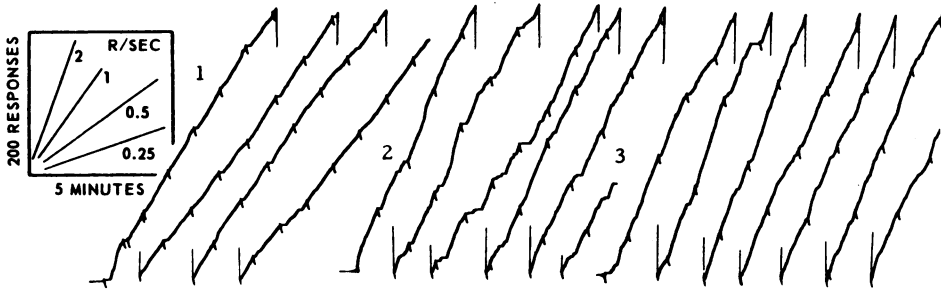


Fig. 18. Transitory characteristic of FI scallop.

which appeared during the earlier sessions never reappeared although the subject had eight more sessions on FI 1.

Ferster and Skinner make mention of the instability of the FI pattern and point out that the curvilinear pattern may be replaced by ones which are linear or which have irregular characteristics. From time to time, however, the curvilinear one is re-developed. This was not found to be the case here. Once the pause and acceleration to a high terminal rate was replaced by responding at a high constant rate or by responding with some irregular rate pattern, the curvilinear pattern never reappeared.

Effect of Variation of Reinforcement

When Record 16-A was discussed earlier, attention was called to the loss in overall rate toward the end of the session—an outcome which resulted from a failure to maintain the terminal rate. This was interpreted as being due to a reduction in reinforcing effect of the trinkets used. The same hypothesis was used in part when Records 16-B and 16-C were discussed. In that case, an attempt was being made to explain the low, constant rates of responding found after 10 sessions on FI schedules. Although support for this explanation was obtained from earlier research on FR schedules, it was deemed necessary to re-investigate it within the context of FI scheduling. Therefore, manipulations of reinforcement were made for a number of subjects showing the low, constant-rate response pattern.

Doubling Number of Trinkets. In Fig. 19 are the records of three successive sessions of a child on FI 1. The first (19-1) is a record of her tenth session on FI 1. At the beginning of the eleventh (19-2) the number of trinkets given at each

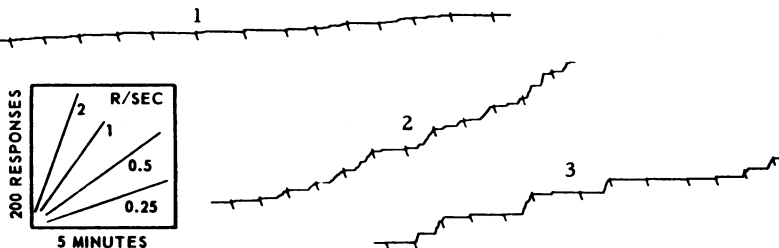


Fig. 19. Effect of doubling number of trinkets.

reinforcement was doubled. The almost immediate consequence of this was to increase the rate near the end of each interval. The number of trinkets was reduced to one for the third session (19-3). A few instances of acceleration to a high terminal rate occurred, but by and large the performance returned to its former low, constant-rate pattern. These results are typical of most subjects reinforced with trinkets. In addition, essentially the same results were obtained when similar manipulations were made with pennies instead of trinkets.

Use of Reinforcing Pictures. In spite of the fact that the number of pennies or trinkets given at reinforcement was increased, many children complained of a lack of "novelty." Moreover, they reported the relatively long intervals between reinforcements to be aversive. This occasionally caused a child to stop coming to his experimental sessions; or worse, if he came, caused him to engage in exploratory activities which produced irregularities in his record. A number of procedures were tried in order to eliminate this difficulty; only one, however, proved to be successful. This entailed projecting a colored slide on the 16-inch-by 16-inch translucent screen in front of the subject during the interval. When the subject was reinforced, a buzzer sounded, a red light was turned on, some sort of "prize" or combination of prizes was delivered, and the colored slide then present was replaced by a new one. Thus, when the red light and the buzzer were terminated after 2 seconds, the subject found a new picture on the screen.

The first record of Fig. 20 is that of a child being reinforced with the joint presentation of a penny and a trinket on an FI 1.5. At the beginning of the following session (20-2), pictures were added during the interval. The subject quickly developed high terminal rates which were usually sustained throughout the interval. The same result was obtained from other subjects reinforced in this way. In addition, many of those subjects who had not paused regularly before the introduction of the pictures did so afterward.

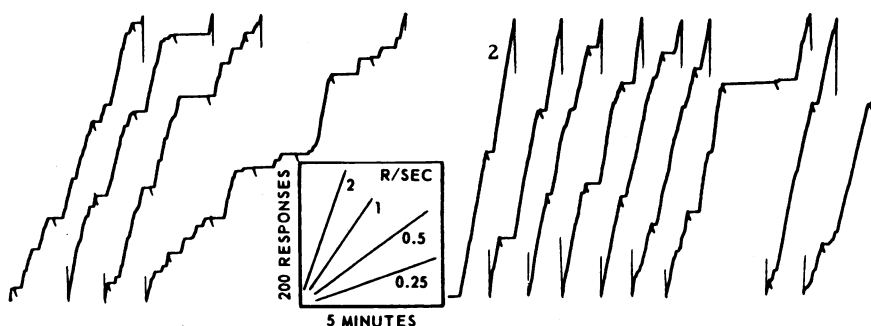


Fig. 20. Addition of reinforcing pictures.

Pictures were also added for several subjects who were responding at a low constant rate and whose rate had not increased when the number of trinkets or pennies given at reinforcement was doubled. Figure 21 contains the records of two subjects on FI 1 being reinforced with two trinkets. These are Records 21-A-1 and 21-B-1. Pictures were added at the beginning of the next session (21-A-2 and 21-B-2). Over-

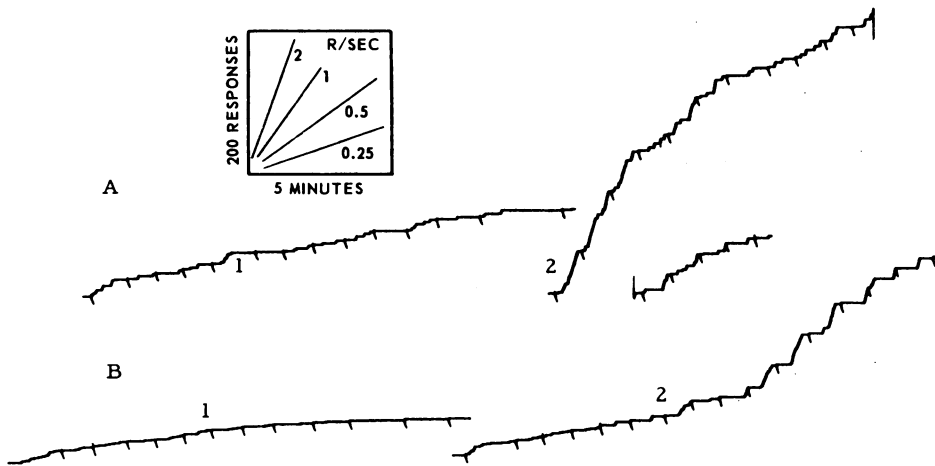


Fig. 21. Effect of pictures on low rates.

all rate was increased in both instances. Typical FI behavior, however, was produced only with the second subject.

The question arises as to why the addition of pictures in this particular way produced a more regular acceleratory pattern. As was indicated earlier, it was designed to supply novel experiences so that the subject would continue coming to the experiment and so that uncontrolled, competing behavior during the intervals would be reduced. The pictures obviously could have had these effects without producing the changes it did in the rate pattern. One explanation is that the change in pictures at the time of reinforcement constituted an additional positive reinforcer. As a possible control a few children were run in the usual way except for the addition of a projected picture during reinforcement. This procedure was found to have no effect. It must be admitted, however, that little research was done on this, and if such possibly relevant parameters as duration of projection had been investigated, a change might have been effected. This will be done in the future.

Another possibility is that the change in pictures at the time of reinforcement might be interpreted as the removal of an aversive stimulus. Many children reported that they enjoyed looking at a picture for a few seconds, but then grew tired of it and actually worked to get rid of it. The implications of this hypothesis are important indeed in that the acceleration to a terminal rate reported for lower organisms responding for homeostatic reinforcers may be in part for positive consequences and in part for the removal of an aversive one.

The more regular pausing after reinforcement could also be explained in terms of competing behavior which is more reinforcing at that particular time. It is unlikely indeed that a subject does nothing when a pause occurs in the record. It seems much more plausible that he is engaging in other behavior. Thus, in this case, observing behavior may be competing with operating the manipulandum. The difficulty with this explanation is that observing and pressing are not actually physically incompatible. Moreover, this hypothesis does not account for the higher, better sustained terminal rate.

One final possibility exists: that the picture, although not correlated with lapse of time, constitutes for the subject a better stimulus basis for the temporal discrimination involved with the FI schedule than does a homogeneously illuminated field. At the present time, none of these hypotheses has been thoroughly investigated.

Use of Large FI's

In a few instances, subjects were shifted from FI 1 to FI 2. These were subjects who were responding at high rates on FI 1 but who failed to show the FI scallop with any regularity. Representative records of the results of this procedure are depicted in Fig. 22. Record 22-1 is that of a subject on an FI 1. The succeeding records (22-2 and 22-3) are of his next two sessions on FI 2. Because the FI 1 records are so irregular, little of a systematic nature can be said about the irregulari-

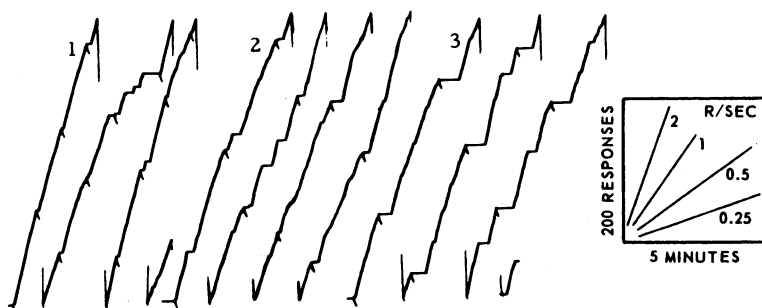


Fig. 22. Shift from FI 1 to FI 2.

ties of the FI 2 records which reflect the development of new contingencies. The FI 2 records, however, are much more typical of fixed-interval responding than are the FI 1 records. This suggests that longer intervals perhaps are required for some subjects to feel the contingencies. Unfortunately, this was impossible to investigate in many instances because subjects refused to remain in the experimental cubicles or to return for further sessions when the intervals were longer than 2 minutes.

Summary of Performance on Fixed-interval Schedules

1. Two procedures were found to be satisfactory for beginning subjects on fixed-interval schedules of 1 minute (FI 1). These were: to start subjects on a VI 0.5 and then shift them to FI 1, or to begin them initially on an FI 1 without any previous experience of intermittent reinforcement. Beginning subjects on an FI 0.5 or on small ratios frequently delayed the development of FI-like behavior when shifted to FI 1. Prolonged use of small ratios also produced irregular, burst-type responding in the later FI performance.

2. Subjects begun on an FI 1 usually showed an initial acceleration over the first five or six reinforcements of the first session. Subjects on VI 0.5 or small ratios did not manifest this acceleration of rate.

3. Most children proved to be quite sensitive to the FI 0.5 and FI 1 schedules, many showing the pauses and acceleration to a terminal rate after as few as six or seven reinforcements. The FI scallops found with children resembled those reported

for lower organisms. Irregularities, however, often obscured the acceleratory pattern and the transition from pausing to the terminal rate was found to be more abrupt than those reported for lower organisms. A few subjects were never controlled by the FI schedule.

4. Deviations such as knees, multiple runs, second-order effects, and negative acceleration were found superimposed on the FI scallop.

5. Negative acceleration, that is, the failure to sustain terminal rate, appeared to be due to the decline in the reinforcing effect of the trinkets and pennies used in these experiments. Doubling the number of pennies or trinkets given and increasing intersession intervals ameliorated this in some subjects.

6. The most powerful motivational manipulation was the addition of projected pictures to the already existing aggregate of reinforcers. This was done by having a picture projected on a screen, before the subject while he responded. When he was reinforced, pennies, trinkets, or a combination of the two were delivered; in addition, the picture was changed, so that when the 2-second reinforcement interval had terminated, the subject saw a new picture. This procedure produced regular pausing after reinforcement and high terminal rates which were sustained by most subjects.

7. The FI scallop was transitory in many subjects, appearing for a time and then disappearing. Unlike the comparable phenomenon reported by Ferster and Skinner, once the scallop disappeared, it never returned.

8. Very little research was done on FI schedules which had durations greater than 1.5 minutes. On a few occasions, FI 1's were increased to FI 2. In most of these instances, subjects gave more stable FI-like behavior with the FI 2 than with the FI 1.

PERFORMANCE ON VARIABLE-INTERVAL SCHEDULES

Initiating Reinforcement on VI Schedules

Few if any difficulties were encountered in beginning subjects on variable-interval schedules. Subjects were usually begun on a variable-interval schedule of 0.5 minute (VI 0.5) and then shifted to a 1-minute schedule (VI 1), or were begun initially on a VI 1. Some children showed an initial acceleration of rate over the first three or four reinforcements before stabilizing at a constant rate. In few instances was the acceleration as extensive as with the FI 1's; and most subjects showed no acceleration, but responded at a constant rate almost from the beginning of the session. In all cases the VI performance of children resembled that previously reported for other organisms. Over-all rates during the second session were almost always higher than they had been on the first. Sometimes, this could be attributed to the low rate at the beginning of the first session. Usually, however, rate differences were not restricted to such small portions of the record. Most subjects showed drops in rate on the third session and then stabilized at this rate for the next several sessions. A few others continued to show slight rate increases for four to five sessions before declining and stabilizing.

In Fig. 23 are the records of the first three sessions of two subjects. At the beginning of his first session (23-A-1) the first subject gradually accelerated until reaching a constant rate. Over-all rate during his second session (23-A-2) was

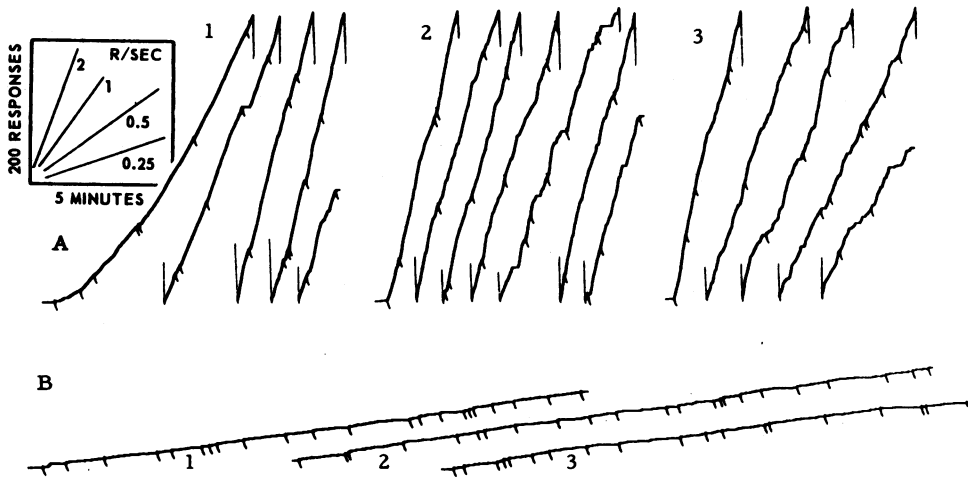


Fig. 23. Representative VI 1 records.

higher. During his third session (23-A-3) his rate declined, and it was at this value that he stabilized for the next several sessions.

The low rates of Records 23-B-1, 23-B-2, and 23-B-3 are typical of approximately 20 per cent of the subjects on VI 1. Even at this low value, the rate during this subject's second session (23-B-2) was slightly higher than during the first (23-B-1). As with the previous subject, it fell slightly during the third (23-B-3).

Variation of VI Tape

In addition to this gradual increase and decrease in rate, other intersession changes were observed. For the most part, these seemed to be dependent on the use of a particular VI tape and the loss of reinforcing effect of the trinkets. More than half of the subjects on VI 1 schedules made use of a particular tape composed of 22 intervals ranging from 2 to 120 seconds. After four or five sessions, a different VI 1 tape was substituted. This one was composed of 15 intervals ranging from 10 to 100 seconds. After three to four sessions on this tape, many subjects began producing irregular records with consistent pausing after reinforcement. A third tape closely resembling the first was then substituted. Within two sessions after the substitution of this tape, most subjects showed a rate increase and a reduction in pausing.

Figure 24 contains the records of two subjects showing this change. The first record (24-A-1) is that of a subject after four sessions on the second tape. The second (24-A-2) is his record after two sessions on the third tape. Records 24-B-1 and 24-B-2 reflect the same changes for another subject.

Effect of Variation in Reinforcement

The fact that some subjects did not respond to the changes in tapes suggested that the trinkets then in use had lost some of their reinforcing effect. New ones therefore were substituted. In Fig. 25 are the records of two subjects for whom both changes were made. Record 25-A-1 is that of a subject whose performance showed deteriorative changes after the introduction of the second tape. The third tape was

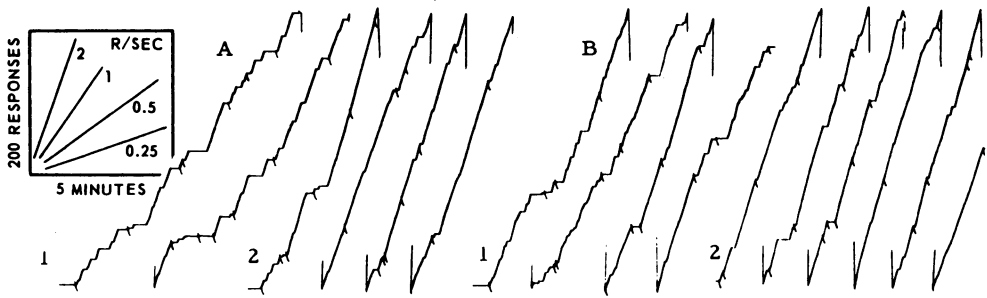


Fig. 24. Effect of changing VI 1 tape.

then substituted. His performance two sessions later is depicted in the next record (25-A-2). Rate continued to decline, and grain and pausing became more pronounced. Different trinkets were then substituted. The record of his session after this change had been effected (25-A-3) indicates that almost all grain and pausing were eliminated, and rate was increased.

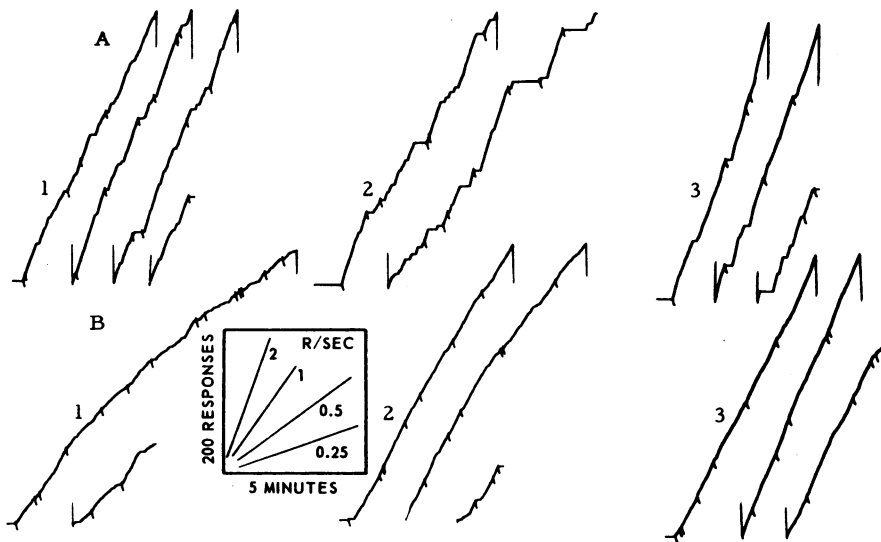


Fig. 25. Effect of changing tape and type of trinkets used as reinforcers.

Records 25-B-1, 25-B-2, and 25-B-3 reflect the effect of the same sequence of changes for another subject. This subject, however, responded favorably to both the tape and the trinket change.

Effect of Increasing Intersession Interval

Intersession intervals were also increased in an attempt to ameliorate the decline in reinforcing effect of the trinkets. Although increases of 1 to 2 weeks were usually unsuccessful, increases of 4 weeks were successful. Representative records are presented in Fig. 26. The first three records (26-1, 26-2, and 26-3) are those of

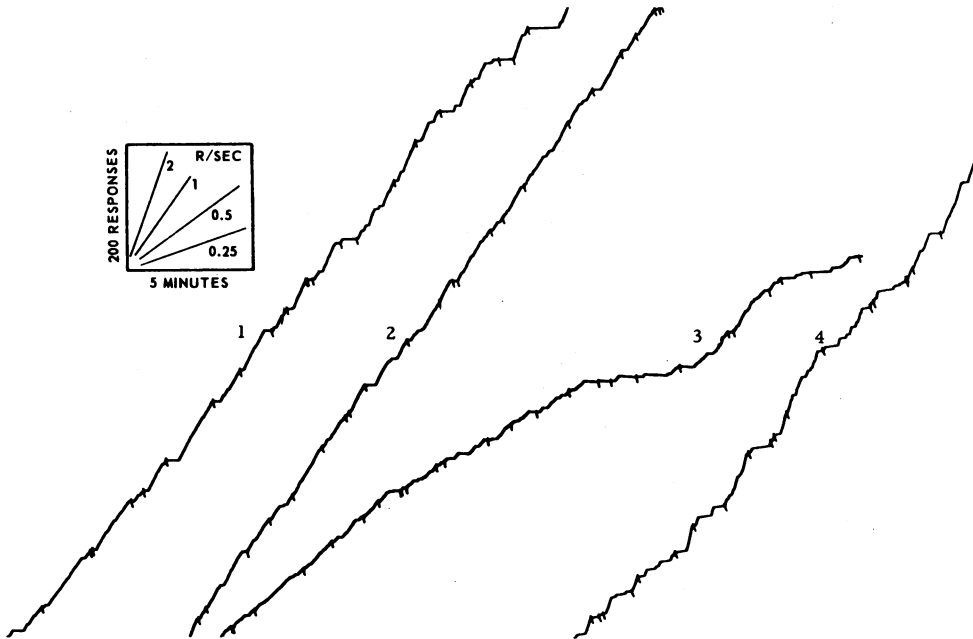


Fig. 26. Effect of increasing intersession interval.

the seventh, eighth, and ninth sessions of a child on VI 1. Her tenth session (26-4) was conducted after an intersession interval of 5 weeks. This subject was given a second intersession interval of 5 weeks between her fifteenth and sixteenth sessions. On this occasion, however, she failed to show any rate recovery. This was true of all subjects for whom the intersession interval was increased after many experimental sessions.

Some subjects failed to show a rate recovery even when the 5-week intersession interval was introduced relatively early, that is, after five or six sessions. This was particularly true for those subjects whose rates had dropped to a very low value. Records 27-A-1 and 27-A-2 illustrate this point. Sometimes, these low rates

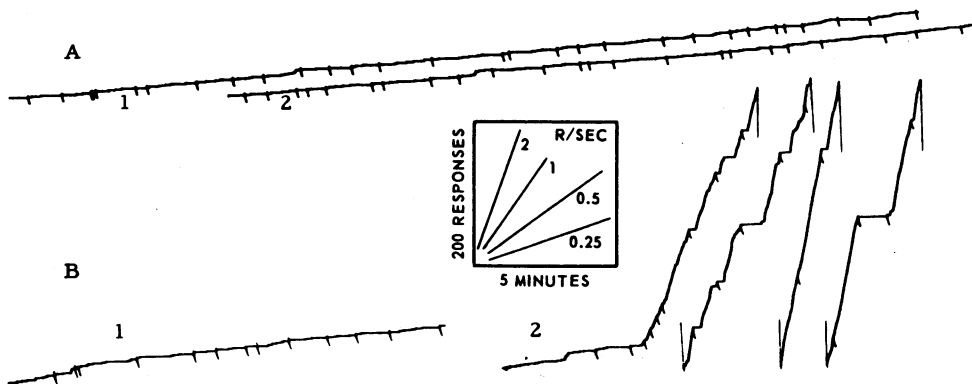


Fig. 27. Low VI 1 rates increased by use of small ratios but not by motivational manipulations.

could be increased by putting subjects on small ratios. However, this was successful only if the subject occasionally responded in bursts. Records illustrative of this are also included in Fig. 27. Record 27-B-1 is a record of part of a session on VI 1. Although this subject had a low rate, he sometimes responded in bursts of six or seven responses. At the beginning of his next session (27-B-2), he was put on an FR 10. After three reinforcements, he began responding at a much higher rate. He was given three more reinforcements on FR 10 and then shifted to FI 1.

Performance on Variable-interval Schedules

1. Most subjects were begun on variable-interval schedules of 0.5 or 1 minute without difficulty. In general, performance by children on VI schedules closely resembled that found with other organisms.

2. During the first session, some subjects showed initial accelerations of rate over the first four or five reinforcements before reaching a constant rate. Most, however, did not.

3. The rates of almost all subjects increased during their second sessions and then fell during their third. Most subjects stabilized at approximately this value for several sessions. A few subjects continued to show rate increases for five or six sessions before declining.

4. Not all VI tapes were found to be equally good in producing constant rates of responding or responding free from pauses after reinforcement. Tapes having too few short intervals produced pausing and generally irregular records. Children appeared to be especially sensitive to changes in VI program tapes.

5. Decline in reinforcing effect of the trinkets produced a decrease in rate, an increase in grain, and, in some instances, pausing after reinforcement. This deterioration of performance was ameliorated in part by changing to new types of trinkets and by increasing the inter-session interval. However, the latter was successful only if introduced early in training.

6. Almost all motivational manipulations were unsuccessful in increasing the rate after it had dropped to very low values. It could sometimes be increased by using small ratios, but this was successful only if the subject occasionally emitted a burst of responses.

DISCUSSION

Analyses of FR, FI, and VI data indicated that in most instances the performance of children was similar to that reported for other organisms. The implication of this is that *almost* as much experimental control can be gained over the behavior of children as that of lower organisms. Control by the schedules in the present research was not so complete as it has been with lower organisms. The child data, especially those obtained with fixed-interval schedules, were not so lawful as those reported for lower organisms. A discussion of the variables which could have produced these irregularities and their implications for future research seems in order.

One of the more obvious procedural differences in the two types of research is that concerned with the interaction of subjects and the experimenter. Whereas this interaction can be minimized or held relatively constant in lower-animal research, it cannot be in child research. In the present case the experimenter called for his subjects, brought them to the laboratory, and later returned them. This entailed going to homes, kindergartens, and schools. It also entailed, in many instances,

interacting with teachers, school officials, and parents in the presence of the subjects. During the time a child was walking or riding to and from the laboratory, he engaged the experimenter in conversation. If several children were present, they frequently talked to one another. All of these social interactions temporally contiguous with responding in the experimental situation undoubtedly influenced the data. Unfortunately, the approval of the experimenter rather than the trinkets all too frequently became the effective reinforcer.

Inability to bring subjects to the experimental situation at desired times also contributed some uncertainty. Reasons for this included illness, being out of town, or the occurrence of holidays. The latter incidentally had very interesting effects. For example, even though Christmas vacation produced an intersession interval of almost 1 month, few if any children showed increases in rate or any of the other manifestations usually accompanying intersession-interval increases that long. A similar phenomenon seems to have occurred at Easter. Almost all children showed elevated rates before Easter, and lowered ones afterward. Other extra-experimental changes apparently had similar effects. A child who had responded with a high rate on a VI 1 showed a much lower rate after receiving a pony as a gift.

Brief experimental sessions also lessened control. Many children refused to work longer than 20 to 30 minutes. In other instances, schools and kindergartens demanded that they be returned within that time. From a different point of view, this was desirable in that it limited the number of trinkets the child could "win" and thus delayed his accumulating many duplicates of every type of trinket. Unfortunately, however, such short sessions hardly gave the schedules an opportunity to start controlling.

Many other complicating circumstances could undoubtedly be enumerated and discussed. All undoubtedly would contribute to the general idea that rigorous schedule control with children is impossible. Such an idea, although partially true, has misleading implications. The present data indicate that in spite of all these difficulties, the reinforcement schedules were able to exercise surprisingly effective control. More importantly, this was done even though deprivation levels were low and reinforcers were weak. If more powerful reinforcers could be discovered and used, the previously discussed lack of extra-experimental control, short sessions, etc., might come to have little or no effect.

SUMMARY

Children varying in age from four to eight years operated telegraph key or Lindley manipulanda in individual experimental cubicles. They were reinforced intermittently with trinkets, pennies, and projected pictures. Experimental sessions were 20 to 30 minutes and usually occurred once each week. The schedules of reinforcement used were fixed ratios, fixed intervals, and variable intervals. Approximately 200 children participated in this research, many returning for more than 20 sessions. Almost all of the data attested to the feasibility of controlling the behavior of children by means of various schedules of reinforcement.

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