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ADDITIONAL TECHNIQUES FOR PRODUCING MULTIPLE-SCHEDULE CONTROL IN CHILDREN[1, 2]

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The subjects in these experiments were 132 children, varying in age from 4 to 7 years. These experiments were designed to assess the efficacy of various multiple scheduling procedures in producing reliable stimulus control. The schedules studied were multiple fixed-ratio–extinction (mult FR EXT); multiple differential-reinforcement-of-other-behavior–fixed-ratio (mult DRO FR); multiple differential-reinforcement-for-low-rate–fixed-ratio (mult DRL FR); and multiple fixed-interval–fixed-ratio (mult FI FR). In addition other techniques were investigated, such as presenting FR's in blocks; increasing the size of the FR's; attaching a DRL to the FI members; temporarily shifting to new schedules; and adding an external clock to the FI's. These experiments yielded the following results.

1.) Strong stimulus control was produced by mult FR EXT, mult DRO FR, and mult DRL FR schedules. Control for mult FR EXT was mediated principally by the individual stimuli, though on occasion it was dependent in part on the change of stimuli. The mult DRO FR was found to be highly useful for those children who had very high initial rates or who were generally uncooperative and unmanageable.

2.) Contrary to a previous finding, some subjects were brought under stimulus control by means of mult FI FR schedules without the aid of additional procedures. Most, however, were not. Additional techniques found to augment the development of mult FI FR control included: (1) presenting FR's in blocks; (2) increasing the size of the FR's; (3) attaching a DRL to the FI component for a time and later removing it; and (4) shifting to a mult DRL FR, developing control, and then returning to the original mult FI FR.

3.) Addition of an external clock to the FI components of the mult FI FR had several effects. Strongest control, including well-developed acceleratory patterns during the FI's, was developed in those subjects who had first been shifted from a regular mult FI FR to a mult FR EXT, brought under control, and then returned to the mult FI FR with the clock added. The added clock also produced strong control if it was present when the subject was first begun on a mult FI FR schedule. In some cases, the addition of the clock produced control in subjects who had not been controlled previously by the regular mult FI FR, but these were always subjects who had high rates. The addition of the clock first lowered the rate, then produced control.

In an earlier paper, I reported some experimental procedures which established stimulus control in normal, preschool children (Long, 1959) when used with multiple fixed-interval–fixed-ratio schedules. In a recent series of articles, Orlando and Bijou (1960), Bijou and Orlando (1961), and Bijou (1961) reported how multiple-schedule control was established with other schedules and, in some instances, with children drawn from different populations. The purpose of this paper is to add to the growing fund of information on multiple scheduling in children by describing additional techniques and the data they produced.

METHOD

Subjects

The subjects in these experiments were 132 children, varying in age from 4 to 7 years. Of these, 120 attended local nursery schools; the remaining 12 were in the first grade of a neighboring elementary school. These experiments were conducted over a 2-year period.

Apparatus and Procedure

The apparatus and general procedure have been described in detail in an earlier article

[1]This research was supported by USPHS Grant No. M-2879.

[2]The author wishes to thank Mrs. Kathleen Fink, Mrs. Jane Cooke, and Miss Diane Scrivener for their valuable assistance with this research.

(Long, 1958). Briefly, each child was placed in an individual cubicle, where he sat at a console which housed a Gerbrands Universal Feeder, various colored lights used as discriminative stimuli, and an encased telegraph key. He operated the key in the presence of either a red or green light, each correlated with a different schedule. When the child was reinforced, the red or green light was extinguished, and a yellow one was activated. At the same time, a buzzer sounded and a trinket was delivered. The yellow light and buzzer remained active for approximately 4 sec. At the end of that time, these stimuli were terminated, and either the red or the green light was activated. Experimental sessions lasted approximately 45 min, during which time most children earned 50 to 60 trinkets.

A number of different schedules were studied: multiple fixed-ratio–extinction (mult FR EXT); multiple differential-reinforcement-of-other-behavior–fixed-ratio (DRO FR); multiple differential-reinforcement-for-low rate–fixed-ratio (mult DRL FR); and multiple fixed-interval–fixed-ratio (mult FI FR). These schedules were studied in an effort to understand their individual controlling properties. A number were also used as shaping procedures before the mult FI FR schedules were introduced. In addition other techniques were investigated, such as (1) presenting FR's in blocks, (2) increasing the size of the FR's (3) attaching DRL's to the FI's (4) temporarily shifting to a different schedule, and (5) using an external clock with the FI's.

RESULTS

Mult FR EXT

Development of Control. A multiple schedule that appeared to have considerable value was the mult FR EXT.[3] In the present series of experiments, a small fixed ratio, either an FR 5 or FR 10, was paired with a red light. After the child had run off the ratio and was reinforced, a green light was presented and the schedule was changed from an FR to extinction. If the child had not responded after a brief period of time, the green light was replaced by a red one, and the extinction schedule was replaced by a fixed ratio. If he had responded in the presence of the green light, the shift was delayed until a predetermined period of time had elapsed since his last response. After stimulus control had once been developed, the response-delay interval was gradually increased; and following this, the fixed ratio was increased.

This schedule proved to be especially powerful in establishing stimulus control in children who were refractory to control by mult FI FR schedules because of their high initial rates. Records A-1 and A-2 of Fig. 1 are those of the first and second sessions of a subject having such rates. Approximately

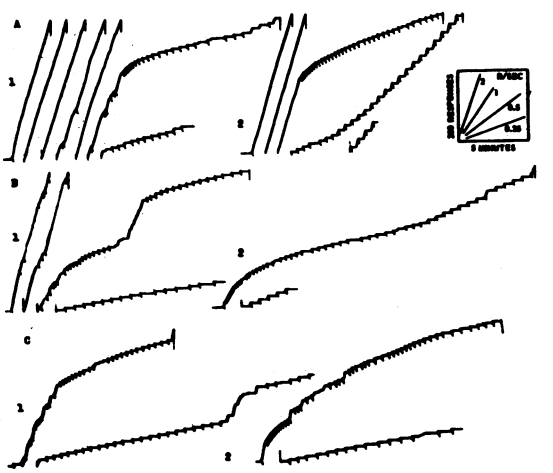

Fig. 1. Development of stimulus control with mult FR EXT schedules.

2300 responses were emitted in the first session before the schedule began exercising control. The initial response-delay interval was 2 sec; as control developed, it was increased to 35 sec, at which point control broke down. The delay was reduced to 25 sec and then increased to 30 sec. A fixed ratio of 5 was used throughout this session. At the beginning of his next session (A-2), approximately 1100 responses were required before control was redeveloped. The response-delay interval was increased rapidly from 4 to 24 sec. The ratio was then increased from 5 to 25 without loss of control.

The data of the second subject (B-1 and B-2 of Fig. 1) are representative of those subjects whose high initial rates did not persist; control in this case began to appear after approxi-

[3]The author is indebted to Professor Bijou for having called this schedule to his attention. It is described in some detail in a recent article by Bijou and Orlando (1961).

mately 850 responses. After control began to develop in the first session, the response-delay interval was increased rapidly to 25 sec, but later had to be reduced to 15 sec and then increased again. During the second session, the delay interval was increased to 36, and the fixed ratio was increased to 10 without loss of control.

Records C-1 and C-2 are those of a subject who had a much lower initial rate and in whom control was developed more quickly. During the first session (C-1), only one serious breakdown of control occurred. The response-delay interval had just been increased to 36 sec at that point. It was left at that value, and control redeveloped. During the second session, the FR was maintained at its previous value of 5; however, the response-delay interval, was increased gradually to 60 sec.

Type and Strength of Control. In the three cases just described, stimulus control proved to be strong enough to tolerate schedule increases without serious, permanent breakdown. This was true for almost all subjects. With only the developmental sequences, however, it was not possible to assess the degree to which control was exercised by the individual discriminative stimuli or by the change of stimuli, *i.e.*, green light followed by red. To answer this question, two procedures were used: presenting the red-light–fixed-ratio combination immediately after reinforcement; and reversing the stimuli so that the red light became the S^{Δ}, and the green light became the S^{D} paired with the FR.

Records A, B, and C of Fig. 2 indicate the effects of the first procedure. For the first two subjects, the immediate introduction of the

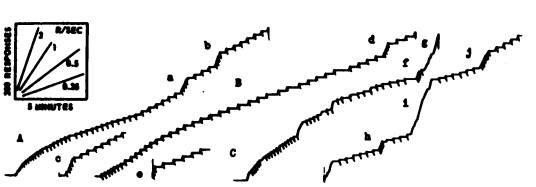

Fig. 2. Effect of presenting the red-light–fixed-ratio combination immediately after reinforcement.

FR and the red light after reinforcement at *a*, *b*, *c*, *d*, and *e* resulted in little or no disturbance. The subjects responded almost immediately to the red light and paused when the green light was again introduced. However, this procedure disrupted the behavior of the third subject somewhat. This child responded immediately to the red light at *f*, *h*, and *j*; but the control of the green light was clearly weakened once it was again used (*g* and *i*). On some occasions, this procedure caused subjects to pause in the presence of the red light when the FR was in effect. These data indicate that control in some subjects was mediated entirely by the individual stimuli, but in others it was dependent partly on the individual stimuli and partly on the change.

Records 1, 2, 3, and 4 of Fig. 3 indicate the effect of reversing the discriminative stimuli and schedules and then returning them to their original correlation. The first five rein-

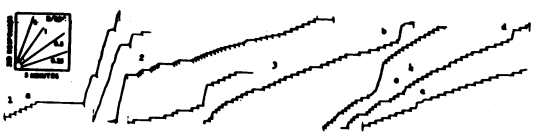

Fig. 3. Effect of reversing the discriminative stimuli and schedules.

forcements of Record 1 indicate strong stimulus control. The response-delay interval was 28 sec, and the fixed ratio was 10. At *a* the stimuli were reversed, so that the red light became the S^{Δ} and the green light the S^{D}. The child at once showed that he was controlled by the change of stimuli rather than by specific stimuli, because he did not respond immediately to the red light, the previous S^{D}, but rather waited until it turned green. At this point, he responded nine times and then paused approximately 5 min before again responding. From that point on, he responded for long periods at a high rate in the presence of the red light. If he paused, he did so for periods well beyond the response-delay interval (2 sec) which was necessary for a change from the red to the green light. At the beginning of the next session (Record 2), the FR was reduced to 5. The response-delay interval was gradually increased from 2 to 26 sec, and as control developed the FR was increased from 5 to 10. At the beginning of the third session, the response-delay interval was reduced to 8 sec and gradually increased to 28 sec. At *b* the original stimulus-schedule correlation was re-established. This change had no effect for two reinforcements, again indicating that control was in part mediated by a change of stimuli. After the second, however, he began to respond at a high rate in the presence of

the green light. The response-delay interval was reduced to 8 sec and then gradually increased to 18 sec, where control again broke down. However, it was re-establisted by reducing the delay interval to 6 sec and increasing it slowly. Strong control was redeveloped during the fourth session (Record 4). The response-delay interval was increased from 6 to 36 sec during the session. On only three occasions (*c*, *d*, and *e*,) were there response bursts in the presence of the green light, and these losses of control proved to be transitory. For the most part, this subject's reversal sequence is typical for all those given reversal training with this schedule. Despite relatively strong stimulus control, no great difficulty occurred. These results also support the earlier conclusion that control in some subjects was dependent partly on the individual stimuli and partly on the change of stimuli.

Research was also conducted to determine whether or not stimulus control would be weakened if the response-delay contingency associated with extinction and the green light was removed. Records A and B of Fig. 4 indicate the effects of removing the delay contingency accompanying the S^{Δ} for an entire experimental session. The S^{Δ} period for the first subject (A) ranged from 8 to 30 sec. For the second (B), it was begun at 20 sec and increased to 36 sec. During the sessions, stable performances ultimately developed in both subjects, despite instances of high rate as well as irregular responding during early parts of their sessions. These records suggest that if strong stimulus control has once been developed, the delay contingency can be removed without serious or permanent loss of stimulus control.

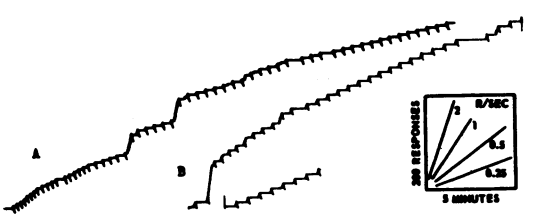

Fig. 4. Removal of the response-delay contingency from the mult FR EXT.

MULT DRO FR

A second schedule used to establish stimulus control is one which reinforced the subject for not operating the manipulandum in the presence of the green light, but reinforced him on a fixed-ratio schedule for operating it in the presence of the red light. Reynolds (1961) has named the first member of this multiple a DRO, inasmuch as it differentially reinforces behavior other than operating the manipulandum. Like the mult FR EXT, this schedule established stimulus control quickly. In some instances it established control where the mult FR EXT had previously failed. Because of its strength, it was used principally with children who were resistant to all other techniques of control. By and large, these were children who had very high initial rates; those who would not remain in their experimental cubicles and who constituted behavior problems generally; and those who only occasionally came to the laboratory, and then only after very long intersession intervals. Records A-1 and A-2 of Fig. 5 are those of a child with a very high rate. Six sessions on mult FR EXT had failed to produce any control. During her first session on mult DRO FR, no control was developed. It did develop during the second session, however; and two different rate patterns are clearly discernible during the last third of the record, when she was on a mult DRO 20 FR 10.

Fig. 5. Development of mult DRO FR control in two subjects with high initial rates.

In contrast with the results of this subject, strong stimulus control was sometimes produced in subjects with high initial rates in a single session. Records B-1 and B-2 of Fig. 5 illustrate such an instance. This child had been on mult FI FR for four sessions and had not been brought under control. Record B-1 is a part of the record of her fourth session. At the beginning of her next session, the schedule was changed to a mult DRO 2 FR 10 (B-2) The DRO was later increased to 24 sec. Why stronger and more rapid control was established here is still not apparent, since no special procedures were used. In all of these experiments the fixed-ratio component was maintained at a constant value of 10; and the

response-delay interval was gradually increased from 2 up to a maximum of 34 sec in the same manner as it had been for the extinction member of mult FR EXT.

Records A-1 and A-2 of Fig. 6 are those of a child who was generally unmanageable. She frequently refused to remain in her cubicle,

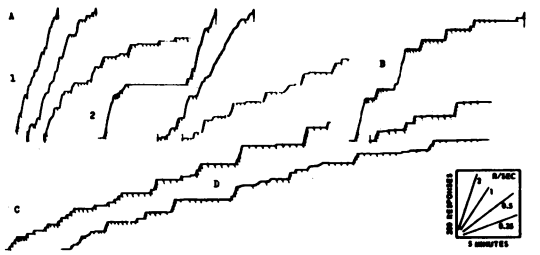

Fig. 6. Mult DRO FR control in other subjects.

and often had to go to the bathroom two or three times during a session. Although a number of attempts had been made, no prior stimulus control had been established. Record A-1 is that of her first session on mult DRO FR. Development and increasing strength of DRO control appear in the last two-thirds of her record. Record A-2 is that of her following session, 6 weeks later. At the beginning of the session, she seemed disturbed, and stimulus control had to be redeveloped. Nevertheless, stable performance was developed during the last half of the session.

Records B, C, and D, of Fig. 6 are first-session records of three subjects who did not have extremely high initial rates and who were generally manageable. In all three cases, relatively strong stimulus control was developed quickly. Here, as in the previous cases, the FR was always held at 10, while the DRO was begun at 2 sec and increased to a maximum of 34 sec. Because this procedure was mostly used for "problem" children, the principal motivation was to see if stimulus control could be developed by any means. Little research was done on the schedule itself, or on its possible use as a shaping technique for later schedules.

Mult DRL FR

A third multiple schedule found to be useful in establishing stimulus control was the mult DRL FR. Some subjects were brought under its control in one session, as Records A and B of Fig. 7 illustrate. Most subjects required three to five sessions, however. Records 1, 2, and 3 of Fig. 8 illustrate a typical

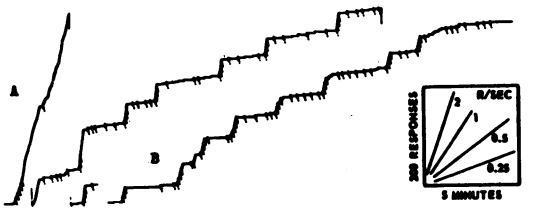

Fig. 7. Development of mult DRL FR control in one session.

developmental sequence. Evidence of control appeared in the first and second records, but a relatively stable performance did not develop until the third session. In all such cases, control was developed by gradually increasing the DRL from an initial value of 2 sec to a maximum of 16 sec; the FR's were always 5 or 10.

The records just discussed are those of a subject who had been on a mult FI FR before being shifted to the mult DRL FR, because

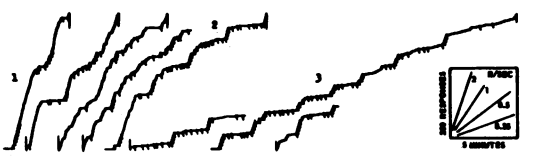

Fig. 8. Typical mult DRL FR developmental sequence.

control had not been established with the mult FI FR. Usually, this shift was effected without any observable transfer effect from the previous schedule. However, Records 1 and 2 of Fig. 9 show poorly developed mult FI FR patterns. During these two sessions the child was on a mult DRL FR but was not controlled by it. When the mult DRL FR did start exercising control (Records 3 and 4), all

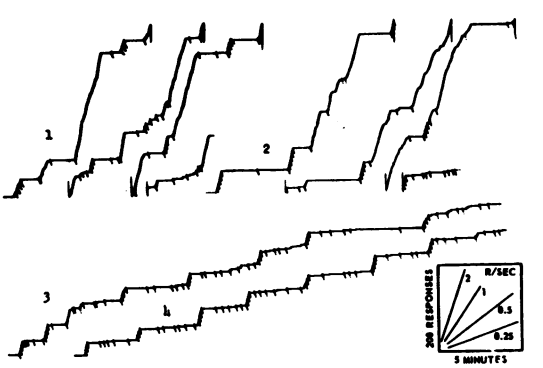

Fig. 9. Effect of prior exposure to mult FI FR on later development of mult DRL FR control.

evidences of the previous poorly developed mult FI FR patterns disappeared. A possible explanation is that this particular subject had been on a mult FI FR with the FR's presented in blocks.

In a few subjects, prior experience on a mult FR EXT also delayed stimulus control with the mult DRL FR. This was not the general rule, however; and even when it occurred, few traces of performances appropriate to the mult FR EXT appeared in the record after the shift to mult DRL FR. The clearest example of transfer occurred with those subjects shifted from chain DRL FR to mult DRL FR. Record 1 of Fig. 10 is that of a subject on a

Fig. 10. Effect of prior exposure to chain DRL FR on later development of mult DRL FR control.

chain DRL FR. During the session, her third, the DRL was increased from 4 to 24 sec; the FR was held at 5. Although control was lost four times, performance was stable during the last third of the session. At the beginning of the next session, the subject was shifted to a mult DRL 4 FR 5. The record for the first third of the session resembles that of the chain DRL FR. Suddenly, however, the subject developed a high rate in the presence of the red light and was reinforced six times within a brief period of time. Similarly, she received five reinforcements in quick succession by spacing her responses in the presence of the green light. Strong stimulus control then developed quickly. This record is representative of all four subjects shifted from chain DRL FR to mult DRL FR.

Mult FI FR: Developmental Procedures

Control with No Additional Techniques. In a previous article (1959), I reported that I had been unable to establish stimulus control with a multiple FI FR schedule unless I used additional procedures. These had included differentially reinforcing the interval and ratio components; permitting simultaneous play with a toy; using a manipulandum which required a greater force to operate; and satiating or "prefeeding" the subjects with trinkets. In the present series of experiments six subjects came under mult FI FR control without the use of additional techniques. Perhaps even more surprising, the control in these cases appeared during each subject's first session. In some cases, early control was relatively strong; in others, it was weak. A second session usually strengthened control. There was rarely any further strengthening beyond this, however; and in several cases, additional sessions actually weakened it.

Performances during the first three sessions of three representative subjects are depicted in Records A-1, A-2, and A-3; B-1, B-2, and B-3; and C-1, C-2, and C-3 of Fig. 11. All subjects were begun on mult FI 1.25 FR 10. The schedule was held at this value during all three sessions for the first two subjects. During the second session of the third subject (C-2), however, the FR was increased to 15; and during her third session (C-3), the FR was reduced to 10 while the FI component was increased to 1.5 min. Weakest control was exercised over

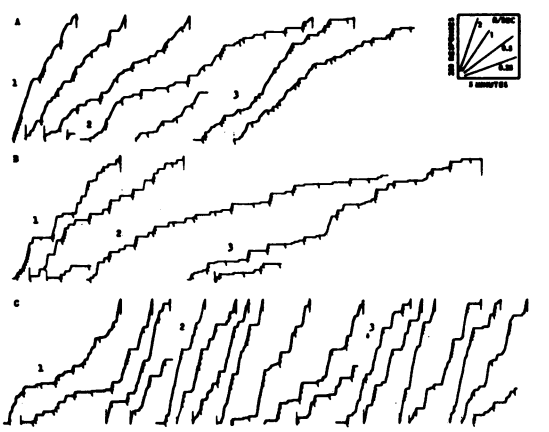

Fig. 11. Development of mult FI FR control without the use of additional techniques.

the first of these three subjects. In this child's case, control was strengthened by a second session (A-2), but was weakened by a third (A-3). With the second subject, control was strengthened by a second session (B-2), but remained essentially unchanged during the third.

Control was strongest for the third subject. Her records are also of interest because of the acceleratory patterns the FI components produced. Strong control was developed during

the first session (C-1), and for the most part it remained equally strong throughout the second and third sessions. The slight adjustments in schedule had little effect on this subject's performance. The increase of the FR during the second session resulted in several instances of low-rate responding during the FI's, but the increase in the FI during the third session had no pronounced or consistent effect.

FR's Presented in Blocks. One of the techniques used to aid in developing stimulus control with FI FR multiples was presenting FR's in blocks of four to six. In many cases, evidences of control appeared during the first session in which this procedure was followed; but strong control usually required four or five sessions. Two representative developmental sequences are depicted in Records A-1 through A-4 and B-1 through B-5 of Fig. 12. The FI performance is the principal difference between the two sets of records. On several occasions during his fourth session (A-4), the first subject showed second-order effects; that is, he responded at a very low rate during the first FI following a block of FR's, and then accelerated his rate over the next two or three FI's so that all of the FI's in sequence gave the appearance of a single large scallop. On other occasions during his third and fourth sessions, he tended to scallop within single fixed intervals. Superimposed on this were occasional ratio-like bursts. In contrast, once control had been developed in the second subject, the fixed-interval rate became very low and constant. Most subjects brought under stimulus control in this way yielded final records which closely resembled Record B-5.

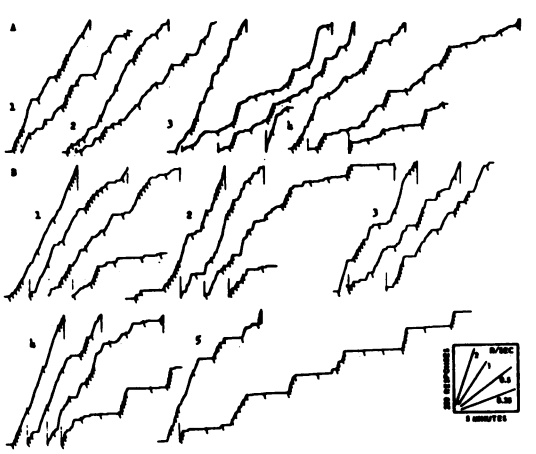

Fig. 12. Development of mult FI FR control with FR's presented in blocks.

Increasing Size of FR. In a few instances, control was developed by the additional procedure of increasing the size of the fixed ratio. The subjects treated in this way were those whose initial rates had been very high. Discriminably different rate patterns were produced in one or two sessions. However, final control was usually weak, and it frequently resembled that expected of a mixed rather than a multiple schedule. The effects of this procedure are depicted in Records A-1, A-2 and A-3; B-1 and B-2; and C of Fig. 13. The first subject was on a mult FI 1.5 FR 10. He had a high initial rate and a slight tendency to pause after long priming runs (A-1). The fixed ratio was increased to 20 at the asterisk. Although the running rate remained the same, the pauses became more marked. The FR was held at 20 during his second session (A-2). Pausing during the fixed intervals became more pronounced. On some occasions, it followed a short priming run; on others, it followed reinforcement immediately. This same trend continued during the third session (A-3). In addition, during this session the running rates for the ratios and intervals became markedly different. A similar effect appeared with the second subject (Records B-1 and B-2). This subject, too, was initially on a mult FI 1.5 FR 10. At the asterisk, his fixed ratio was increased to 25, so that slightly different rate patterns developed for the two schedules. These differences became very pronounced during the following session (B-2). Record C is that of a subject whose performance change typifies that produced in most subjects by this procedure. At the beginning she was on a mult FI 1.25 FR 10.

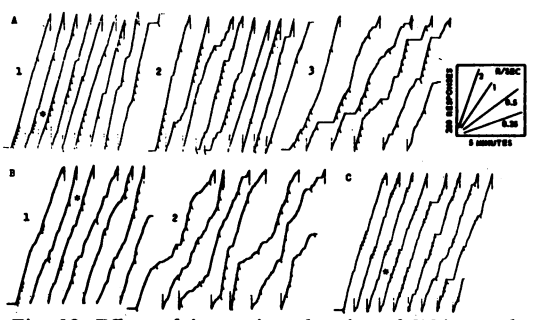

Fig. 13. Effect of increasing the size of FR's on the development of mult FI FR control.

At the asterisk, her fixed ratio was increased to 25. This resulted in the production of long pauses at the beginning of the FI's which followed blocks of FR's. Little or no pausing occurred at the beginning of those intervals that followed other intervals.

Addition of DRL to FI's. Another schedule modification used in establishing stimulus control in children who had high rates entailed attaching a DRL to the fixed-interval component of the multiple. Because this usually resulted in a considerable delay of reinforcement, the FI's frequently had to be reduced until pausing appeared, and then increased to their original value. Records 1 through 4 of Fig. 14 illustrate the development of stimulus control with this method. This child was begun on a mult FI 1.25 FR 10. At the asterisk, a DRL of 1 sec was attached to the FI 1.25. At the beginning of his second session the FI was reduced to 30 sec and the DRL increased to 2 sec. Later in the session the DRL was increased to 3 sec and the FI to 1 min. The FI was increased to 1.25 min at the beginning of his third session; the DRL was increased from 2 to 4 sec later in the session. At the beginning of the fourth session, the DRL was removed, so that the subject was returned to his original schedule, mult FI 1.25 FR 10. Except for a few ratio-like bursts during the FI's, the control was very strong.

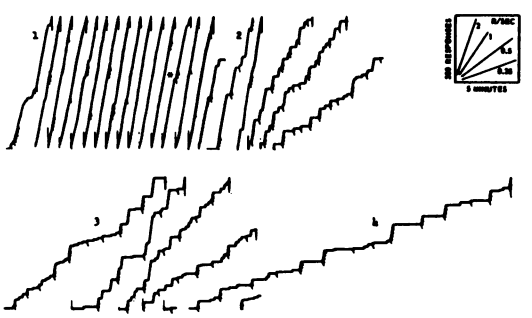

Fig. 14. Development of mult FI FR control with DRL added to FI's.

These records are representative of approximately 50 per cent of the subjects brought under control in this way. The remainder had more ratio-like bursts during the fixed intervals and pauses before ratios. Records A and B of Fig. 15 show examples of this final level of control in two subjects. No reasons for the two different classes of records are readily available. With the subjects above, two more sessions on a mult FI 1.25 FR 10 produced no further improvement of control. Similarly, when other subjects were given further exposure to the mult FI drl FR, there was no further improvement. A few subjects exposed to the added DRL contingency showed little if any improvement of stimulus control, but rather a lowering of running rate. Records C-1 and C-2 of Fig. 15 show an example of this. Record C-1 is a record of this subject's last session on mult FI 1.25 FR 10. Record C-2 shows his performance during his third session on mult FI 1.25 DRL 3 FR 10.

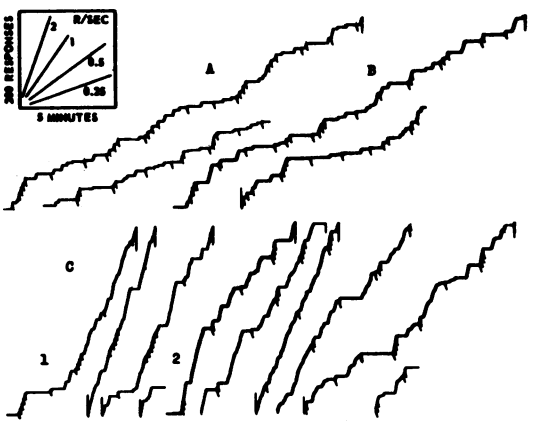

Fig. 15. Instances of less strong mult FI FR control after the use of the added DRL.

Temporarily Shifting to a Different Schedule. Closely akin to the technique just described was that of shifting a subject from mult FI FR to a different schedule and then back. Thus, some subjects on mult FI FR schedules who had not been brought under stimulus control were shifted to either a mult FR EXT or a mult DRL FR; and after control had been developed, they returned to the original mult FI FR. When these procedures were carried out, shifting subjects to a mult FR EXT did not appear to have an augmenting effect if the child were returned to the original mult FI FR. However, if an external clock was added to the FI when he was returned to the mult FI FR, extremely powerful control was developed. This procedure will be discussed in detail in the following section.

When a child was shifted to a mult DRL FR, brought under stimulus control, then returned to the original mult FI FR, strong control was always produced. Records 1, 2, and

3 of Fig. 16 illustrate this. Record 1 shows a first session performance on a mult DRL FR. During the session, the DRL was increased from 2 to 16; the FR was held at 10. During the second session the DRL was increased from 6 to 16, the FR again being held at 10. At the beginning of the third session the

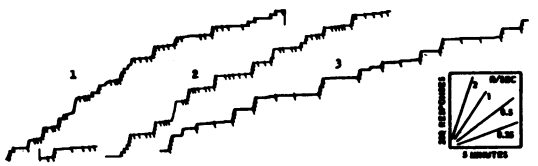

Fig. 16. Effect of prior control by mult DRL FR on later development of mult FI FR control.

schedule was returned to a mult FI 1.25 FR 10. The FR was paired with a red light as it had been when the mult DRL FR was used. The FI was paired with a green light, the stimulus which had previously been paired with the DRL. Record 3 indicates that powerful control was developed almost immediately.

The return to the mult FI FR from the mult DRL FR was sometimes made within a session and after less powerful control had been established with the mult DRL FR. Records A, B, and C of Fig. 17 illustrate typical instances of this. Record A is that of the subject whose previous mult DRL FR performance was depicted in Records B-1 through B-4 of Fig. 9. Control here was strong, and the DRL was increased quickly from 8 to 14 sec. At *a*, an FI 1.25 was substituted for the DRL. Stimulus control remained strong throughout the session. Note should be taken of the acceleratory pattern at *b*. Although a response preceded by a short interresponse time was reinforced, the rate did not increase, nor did the rate pattern change during the succeeding fixed intervals.

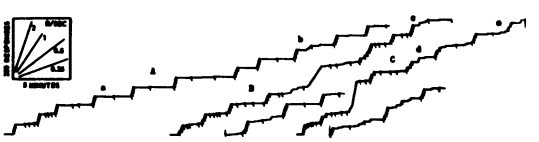

Fig. 17. Mult FI FR control after varying degrees of training with mult DRL FR.

Record B is that of a subject whose previous mult DRL FR records were presented in Fig. 8. At the beginning of this session the subject was placed on a mult DRL 4 FR 10. The DRL was quickly increased to 16 sec, were control broke down. However, it was reestablished without reducing the DRL; and at *c*, an FI 1.25 was substituted for the DRL of 16 sec. Again, control with the mult FI 1.25 FR 10 was strong.

Record C is that of a subject whose previous control was weak at DRL values greater than 12 sec. Thus when the DRL was increased to 16 sec during this session, control was lost. Although it was redeveloped only partially, an FI 1.25 was substituted for the DRL 16 (sec) at *d*. Again, control with the mult FI 1.25 FR 10 remained strong, though not so strong as in the previous cases cited. Note should be taken of the acceleratory pattern at *e*. In Record A a similar pattern was followed by a resumption of the previous low rate. Here, where the DRL control had been weaker, the high rate was temporarily resumed during the next interval.

In general, this proved to be one of the most useful techniques. Stimulus control was usually developed rapidly, and exposure to this schedule usually augmented the development of control with a mult FI FR.

External Clock Added to FI. A final procedure which proved to be highly efficacious in producing stimulus control was the addition of an external clock to the FI component of the multiple. Before this time, each discriminative stimulus had been of constant luminance throughout its duration. It was decided that an external clock might be added by continuously changing the voltage across the filament of the lamp used with the fixed intervals. This was done in the following manner. At the beginning of each fixed interval, an ATC timer was started. When it timed out 11 sec later, 115 VAC was imposed on the primary winding and on the motor of a General Radio Type W5D64S motor-driven Variac. During the next 64 sec, the output voltage of the Variac, and thus the voltage across the filament of the lamp, was gradually increased from zero to 133 V. This procedure caused the translucent screen on which the light was projected to remain relatively dark (0.62 ml) and free of any detectable color during the first 20 to 25 sec of each interval. From that point on, the screen became increasingly bright, terminal luminance being 10.8 ml.

Most subjects begun on a mult FI FR with an added clock were brought under relatively strong stimulus control in one or two sessions

Records A-1 and A-2, and B-1, and B-2 of Fig. 18 are the records of the first and second sessions of two representative subjects. The first subject was begun on a mult FI 1.25 FR 10. During this session, acceleratory patterns developed for the FI's. These patterns were not long lived, giving way to constant low-rate patterns. At the beginning of the second session (A-2), the FR component was increased to 25, but it was reduced to 10 again later in the session. Although the low-rate response patterns persisted for the most part throughout the second session, control remained strong. In later sessions (not pictured here), rate patterns and control remained essentially the same.

The second subject was also begun on a mult FI 1.25 FR 10 (Record B-1). The FR was increased to 25, however, about half way through the session. After this had been done,

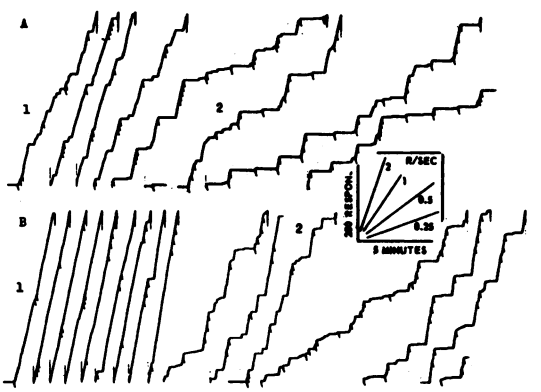

Fig. 18. Development of mult FI FR control with external clock added to FI's.

discriminably different rate patterns began to develop. At the beginning of the second session (B-2), the FR was reduced to 10, but it was increased to 25 again later in the session because control was not developing rapidly. Strong control developed quickly after this change. The fixed-interval rate patterns of this subject are more representative than those of the first subject, inasmuch as most subjects showed acceleratory patterns with FI's.

A clock was sometimes added after a subject had been on a mult FI FR for several sessions. If the subject had not been controlled by the regular mult FI FR, adding a correlated clock did not always bring it about. This was especially true if the overall rate had been low. If the rate had been high, however, the addition of the clock usually improved control. Records 1, 2, and 3 of Fig. 19 illustrate such an occurrence. Record 1 is that of a subject on mult FI 1.25 FR 10. At the beginning of his second session (Record 2), an FI 1.25 was substituted for the FI 1.5, and the clock was added. The initial effect was a reduction in overall rate.

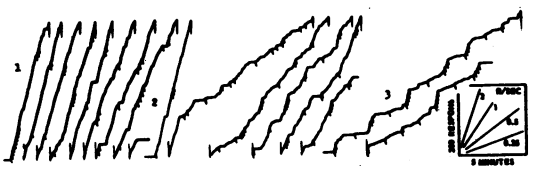

Fig. 19. Effect of added clock on the performance of a subject not controlled by mult FI FR.

But later in the session, control began to develop; and during the third session (Record 3), it became even stronger. The control here is clearly different from that depicted in the previous four records. It is typical of the performance of subjects brought under control in this way however.

On a few occasions a clock was added to the multiple schedules of those subjects who were already being controlled by a regular mult FI FR. For the most part, this either had no effect or produced less good control. Control was improved in three subjects, however, in the sense that an acceleratory pattern replaced the existing constant low rate for the fixed intervals. A case in point is illustrated in Fig. 20. This subject had been on a mult FI 1.25 FR 10. At the beginning of the session described here, a clock was added, so that acceleratory patterns developed for the fixed intervals at *a*, *b*, *c*, and *d*.

Perhaps the most striking stimulus control seen in these experiments was developed in those subjects who after not being controlled by a regular mult FI 1.25 FR 10 were first shifted to mult FR EXT and then returned to a mult FI 1.25 FR 10, but with the external

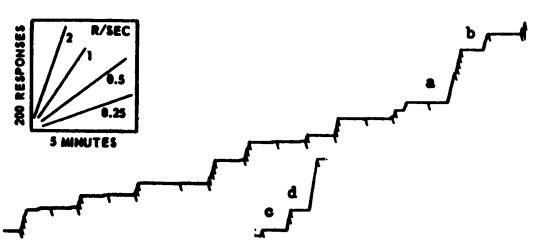

Fig. 20. Effect of added clock on the performance of a subject previously controlled by a mult FI FR.

clock attached to the FI. The performance of two subjects during their first session on the mult FI 1.25 FR 10 with the added clock is depicted in Records A and B of Fig. 21. In both cases, powerful control was developed very rapidly. In almost all instances the FI

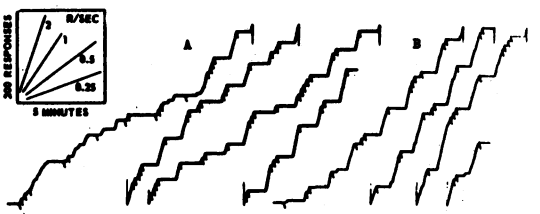

Fig. 21. Effect of previous control by mult FR EXT and added clock on mult FI FR control.

performance of both subjects is characterized by a sudden and rapid acceleration of rate. These rate patterns are similar to those reported by Ferster and Skinner (1957) for the pigeon.

One can only conjecture as to why the control was so strong here. It seems reasonable to assume, however, that the mult FR EXT schedule with its changing stimuli "shaped up" or perhaps improved existing observing behavior. Thus, when later schedules made use of this skill, performance was augmented. Such an hypothesis would account for the fact that previous exposure to the mult FR EXT did not facilitate later control with a regular mult FI FR, but did so when a mult FI FR with an added clock was used.

Mult FI FR: Strength of Control

Mult FI FR without clock. Once stimulus control had been developed with mult FI FR schedules, attempts were made to assess its strength. This was done by reversing the discriminative stimuli when the regular mult FI FR was used and when the added external clock was used by changing the correlation between the clock and elapsed time.

Records 1 through 5 of Fig. 22 are those of a subject on a mult FI 1.5 FR 10 whose stimulus-schedule pairing was first reversed and then returned to its original order after new control had been developed. At the beginning of Record 1 a green light was paired with the FI 1.5; a red one, with the FR 10. The asterisk indicates the locus of the initial reversal. New control can be seen to develop gradually. The original stimulus-schedule correlation was reinstated at the asterisk in the

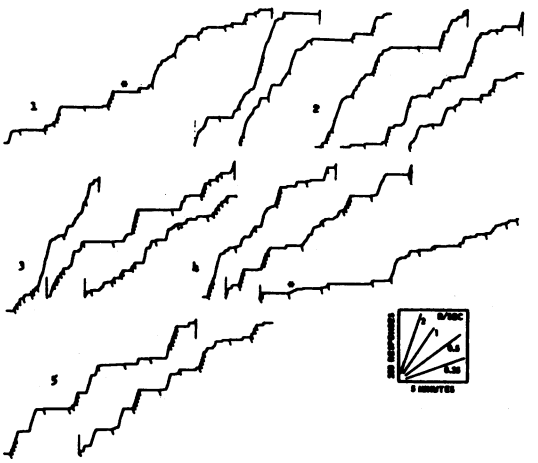

Fig. 22. Typical developmental sequence produced by reversing the discriminative stimuli and schedules.

third excursion of Record 4. Original stimulus control was redeveloped during the fifth session.

The records just discussed closely resemble those of most of the subjects who were taken through this sequence. A few subjects deviated from this pattern, however, and thus merit further discussion. The child whose records are presented in Fig. 23 falls in this class. Earlier records of this child were presented in Fig. 11 (Records B-1 through B-3). This subject was on a mult FI 1.25 FR 10; at the aster-

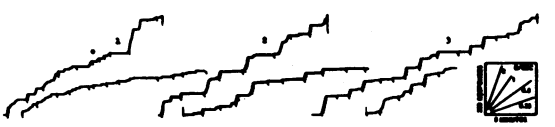

Fig. 23. Rapid behavioral changes produced by stimulus-schedule reversal.

isk in Record 1 the stimulus-schedule pairing was reversed, so that all apparent control was lost. Following this session the subject refused to return to the experiment for approximately 3 months. When he finally did so, the reversed stimulus-schedule correlation was still in effect. In spite of this, strong control was developed quickly (Record 2). When the child returned for his next session (8 days later), the original stimulus-schedule correlation was used; and as the record indicates, original stimulus control was redeveloped quickly (Record 3).

In contrast to this amazing lack of interference, some subjects were never brought

under control of the new stimulus-schedule correlation. Moreover, in these cases is was not possible to re-establish the earlier control when the original correlation was once more used. Records 1, 2, and 3 of Fig. 24 are those of a subject who behaved in this manner. This subject was on a mult FI 1.5 FR 10. At the asterisk in Record 1 the stimulus-schedule

Fig. 24. Loss of stimulus control resulting from reversal of stimuli and schedules.

correlation was reversed. Her performance four sessions later is depicted in Record 2. Because no stimulus control had developed, the original correlation was reinstated for three sessions. Record 3 is that of her final session, after the return to the original correlation. Within that period, little or no recognizable control was produced.

Mult FI FR with Clock Added to FI's. A final way of assessing the strength of stimulus control was by altering the correlation between the added external clock and elapsed time during the FI's. The three records of Fig. 25 indicate the effects of such changes on one subject. At *a* in Record 1 the timer was

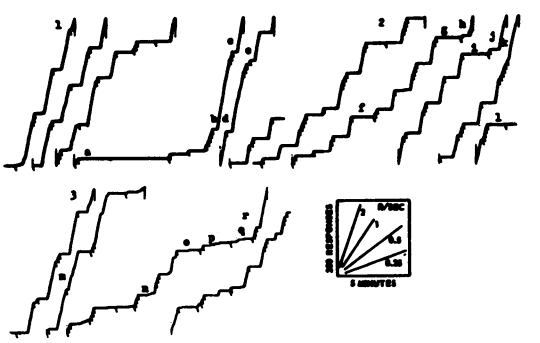

Fig. 25. Effects of altering correlation between the added clock and elapsed time.

not allowed to time out, so that the screen remained dark. This caused the subject to pause for approximately 5 min. At *b*, *c*, and *d* the clock was removed so that the screen became maximally bright immediately after reinforcement. This change did not produce immediate responding; however, it did shorten the pause considerably. At *e* the clock was reinstated, resulting in a subsequent return to earlier FI behavior.

In Record 2 the onset of the clock was delayed for 50 sec at *f*, *g*, *i*, and *l*, resulting in longer than usual pauses. At *h* and *j* the pause was reduced by shortening the duration of the ATC timer from 11 sec to 1 sec, thus causing the screen to grow bright more quickly. At *k* the clock was again eliminated so that the screen was maximally bright immediately after reinforcement, and responding was immediate.

In Record 3 the clock was reversed at *m* and was maintained in that condition until *n*, where it was returned to its original state. This produced reversed scallops during two consecutive FI's. Following this, a new discrimination was developed on the basis of the "new" clock. Interestingly enough the new discrimination did not interfere with later performance when the original clock was reinstated at *n*. At *o*, *p*, and *q* the clock was not activated, so that the screen remained dark and low-rate responding was again produced. At *r* the ATC timer was again set at 1 sec, and responding began earlier.

Similar changes were made for another subject. At *a* (Record 1 of Fig. 26) the onset of the clock was delayed for 50 sec; and at *b*, it had an onset of 1 sec. At *c* the clock was removed and not returned until *d*. These procedures indicated approximately the same type and strength of control for this subject as for the former one. Control in this subject was then tested by changing the values of the FR and

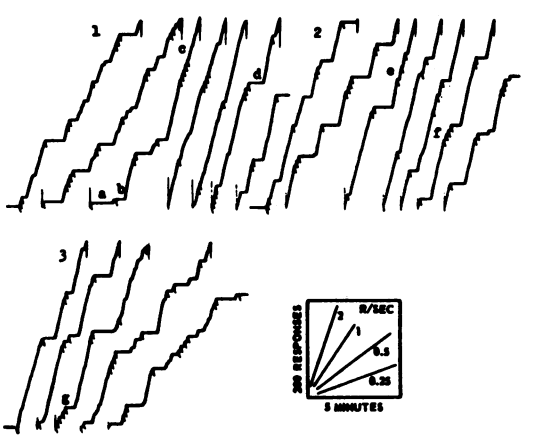

Fig. 26. Influence of altered values of FR's and FI's on clock control.

FI. At *e* in Record 2 the FR was increased from 10 to 25. Although some irregularities in the record before this change make the comparison difficult, increasing the FR appears to have produced a general shortening of the FI pause. When the FR was reduced to 10 again at *f*, the pause returned to its original length. This effect is opposite to that ordinarily obtained when the same procedure was carried out with the regular mult FI FR.

Changing the value of the FI component had an effect which might have been expected with the regular mult FI FR but not with the added clock. This may be seen in Record 3. At the beginning of the session the subject was on a mult FI 1.25 FR 10 with added clock. At *g* the FI was increased to 1.5 min, and the ATC timer was adjusted accordingly so that the clock would still parallel elapsed time. Control remained strong for a time, but later in the session it became much weaker. These results suggest that performances strongly controlled by exteroceptive stimuli are still sensitive to interaction effects between the members of this schedule and to changes in value of the individual members as well.

DISCUSSION

Anyone who has ever run both pigeons and children on a multiple fixed-interval–fixed-ratio schedules cannot help being impressed by the relative ease with which the pigeon is brought under stimulus control and the great difficulty encountered in the child. In attempting to account for these behavioral differences, it is probably wise to point first to possible motivational differences. Indeed, there must be great motivational differences between the highly deprived pigeon working for homeostatic reinforcers and the normal child who volunteers his time and works for charms and trinkets. But one must still answer this question: are these the only important differences? To say that failure to establish mult FI FR control in the normal child is due solely to low deprivation levels and weak reinforcers is to say that all of these failures are due to low or at best irregular rates of responding; general uncooperativeness, *e.g.*, refusal to remain in the experimental cubicles, or perhaps unwillingness to return to the laboratory a sufficient number of times. Admittedly, these behaviors are encountered, and they do interfere with the establishment of control. It is not the total answer, however, because most subjects repeatedly return to the situation; avidly seek the reinforcers, if they are changed from time to time; and respond at high rates for long periods of time. To account for these behavioral characteristics, especially the presistent responding at high rates, it seems necessary to use a supplementary hypothesis. This hypothesis is that the normal child has a history of scheduling before coming to the experiment. This history interferes with his laboratory performance and makes him a difficult subject to bring under control with such weakly controlling schedules as the mult FI FR. Such an hypothesis recognizes that more powerful reinforcers or deprivation procedures must be found and used. It also indicates, however, that this is not enough. In addition, special training or shaping procedures must be developed to undo the effects of prior cultural conditioning in order to render the child a more sensitive laboratory organism. Bijou and Orlando (1961) have already presented a detailed account of a shaping procedure which they found useful in bringing the operant behavior of retarded children under stimulus control. A major aim of this paper had been to indicate the general need for and usefulness of various other shaping procedures, especially those which augment the development of stimulus control with multiple fixed-interval–fixed-ratio schedules.

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