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CHAINED AND TANDEM SCHEDULING WITH CHILDREN[1]

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Children 4 to 7 yr in age were reinforced with trinkets and pennies on chained and tandem schedules. The schedules used were chain DRL FR, chain DRO FR, chain FI FR, tand FI FR, and tand DRO FR. Chain DRL FR and chain DRO FR schedules almost always produced strong schedule and stimulus control, but chain FI FR schedules rarely did if additional techniques were not used. Strong control was produced with chain FI FR schedules, however, if: (a) the FR component was increased in size; (b) schedule and stimulus control was first established with chain DRL FR or chain DRO FR schedules before shifting to the chain FI FR; or (c) an external clock was attached to the FI. Tand FI FR schedules never produced regular or repeatable patterns of responding when additional procedures were not used. Rate patterns resembling those of chain FI FR schedules were produced by tand FI FR schedules, however, if: (a) an external clock was attached to the FI component or (b) control was established by means of tand DRO FR schedules before the tand FI FR was used. Stimulus control was found to be exercised by specific visual stimuli, change of stimuli, and schedule order. Control exercised by schedule order was probably mediated by the child's own behavior which had assumed discriminative stimulus properties.

In earlier papers Orlando and Bijou (1960), Bijou and Orlando (1961), Bijou (1961), and Long (1959, 1962) described techniques for establishing stimulus control by multiple schedules. A major aim of this paper is to demonstrate the usefulness of chained and tandem schedules in producing stimulus control, *i.e.*, different rate patterns in the presence of different discriminative stimuli. In keeping with this aim research was also directed toward determining which stimuli exercise control. A final goal of this paper is to describe the special procedures required to develop component schedule control necessary for demonstrating stimulus control.

The chained and tandem schedules studied were chained differential reinforcement for low rate-fixed ratio (chain DRL FR), chained differential reinforcement for other behavior-fixed ratio (chain DRO FR), chained fixed interval-fixed ratio (chain FI FR), tandem fixed interval-fixed ratio (tand FI FR) and tandem differential reinforcement for other behavior-fixed ratio (tand DRO FR).

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PROCEDURE

Subjects

One hundred and two children varying in age from 4 to 7 yr participated in these experiments. Of these, 88 attended local kindergartens; the remaining 14 were in the first grade of a neighboring elementary school.

The general experimental setting and procedure have been described in detail elsewhere (Long, 1958). Each child sat in an individual cubicle facing a console which housed a Gerbrands Universal Feeder, various colored lights used as discriminative stimuli, and an encased telegraph key. The child operated the key in the presence of either a red or green light, each being correlated with a different schedule. The precise nature of these stimulus-schedule correlations will be considered in detail when each of the schedules is described. When a child was reinforced terminally, the discriminative stimulus then present was turned off, and a yellow light was activated. At the same time, a buzzer sounded and a trinket was delivered. The yellow light and the buzzer remained active for 4 sec, at the end of which time these stimuli were terminated, and the appropriate discriminative stimulus was activated. The chain and tandem schedules described here also entailed interim as well as terminal reinforcement. Interim reinforcement consisted of either a change in discriminative stimuli plus a change in schedules or only a change in schedules. However, it never included the use of the yellow light and the buzzer or the delivery of trinkets.

All of the relay circuitry which controlled these events was housed in a separate room. Experimental sessions lasted 45 to 60 min and in that time most children earned approximately 50 trinkets.

RESULTS: CHAIN SCHEDULES

Chain DRL FR: Developmental Procedures

A chained schedule found to be useful in establishing stimulus control was the chain DRL FR. This was programmed by pairing a green light with the DRL and a red light with the FR. When the green light was present, a response having a latency greater than a predetermined value changed the screen from green to red and the schedule from DRL to FR. Responses preceded by inter-response times shorter than this recycled the timer and kept the subject (*S*) on the DRL schedule until *S* emitted a response satisfying the minimal inter-response time requirement. Once a response had turned the screen red and had put the FR in effect, the *S* could run off the ratio at any rate. Completion of the ratio resulted in the activation of the yellow light and the buzzer and the simultaneous delivery of a trinket. Following the reinforcement, the cycle was repeated. The screen once again became green, and the DRL was again in effect.

Records A-1, A-2, and A-3 and B-1, B-2, and B-3 of Fig. 1 illustrate the development of chain DRL FR control. The first *S* was begun on a chain DRL 2 FR 10. During the course of the first session (Record A-1) the DRL was increased to a maximum of 12 sec; during the second session (Record A-2) it was increased from 4 to 16; and during the third, from 4 to 20. The FR was held constant at 10 throughout all sessions.

The second *S* was also begun on a chain DRL 2 FR 10. During the first session (Record B-1) the DRL was increased to 18 sec; from 4 to 24 sec during the second session (Record B-2); and from 4 to 32 sec during the third session (B-3).

Both *S*s came to show low, constant rates in the presence of the green light and high constant rates in the presence of the red. These records, however, do indicate one major difference in the behavior of the two *S*s. The first *S* rarely showed a zero rate in the presence of the green light. Instead, *S* usually emitted a number of responses at a rate of one every 2 sec prior to the response which produced the FR and the red light. On the other hand, the second *S* usually paused after reinforcement and made no response until the one which produced the red light and the FR. Both kinds of control are representative of the performance of other *S*s reinforced on chain DRL FR schedules.

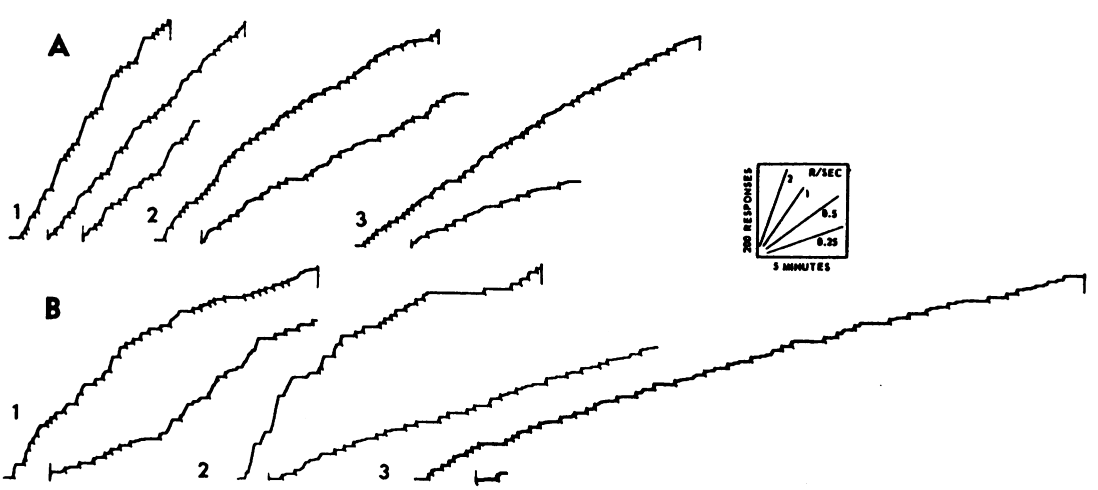

Fig. 1. The development of stimulus control in two *S*s on chain DRL FR schedules.

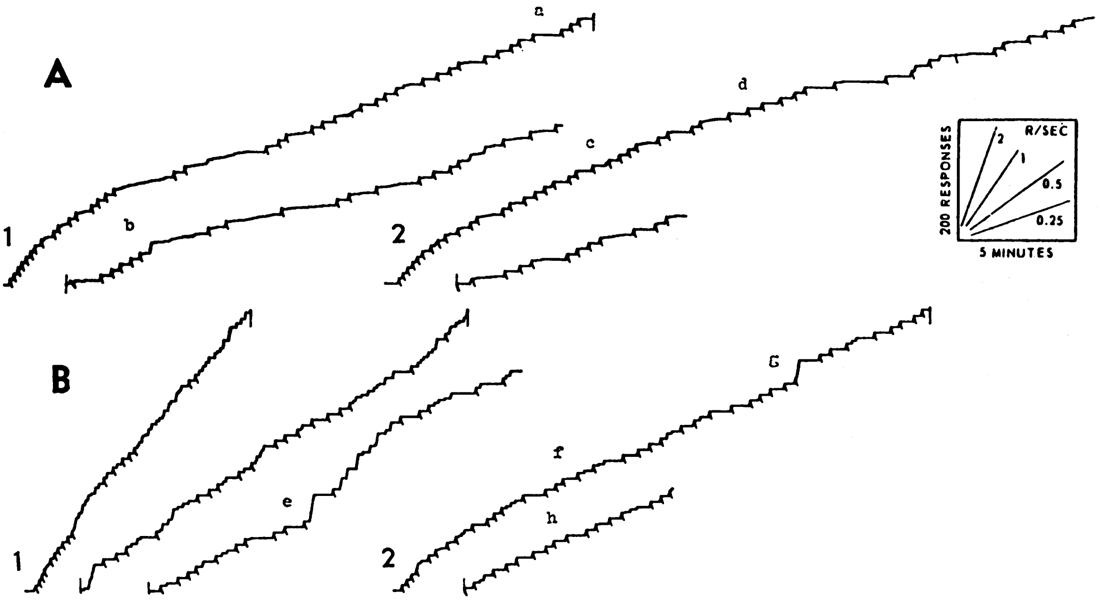

Fig. 2. The effects of reversing the stimulus-schedule correlation in two *Ss* on chain DRL FR schedules.

Chain DRL FR: Strength of Control

The strength of control exercised by the two discriminative stimuli was assessed by reversing the stimulus-schedule correlation in six *Ss*. This was done by keeping the schedules in their original order and reversing the stimuli. Records of two of the *Ss* are presented here. Record A-1 of Fig. 2 is that of one *S*'s second session on a chain DRL FR. At the beginning of the session the schedule was chain DRL 4 FR 10. The DRL was gradually increased to a maximum of 18 sec at *a*. The stimulus-schedule correlation was reversed for the first time at *b*. This change produced a small ratio breakthrough, but following this its major effect was to produce a slight increase in DRL rate and thus to delay reinforcement. All effects were short-lived, and control began to redevelop during the last third of the session. The reversed correlation was kept in effect at the beginning of the next session (Record A-2). The DRL was gradually increased from 4 to a maximum of 18 sec at *c*, the FR being held constant at 10. At *d* the original stimulus-schedule correlation was again put in effect. This change had little if any effect.

Somewhat greater reversal effects were seen in those *Ss* who had come under less strong original stimulus control. Even so, reversed stimulus control developed relatively quickly. An instance of this can be seen in Records B-1 and B-2 of the same figure. Record B-1 is of this *S*'s second session on chain DRL FR. When the stimulus-schedule correlation was reversed at *e*, the schedule was chain DRL 20 FR 10. The change in this case produced an almost immediate ratio breakthrough and a general loss of control during the remainder of the session. Again the reversed correlation was kept in effect at the beginning of the next session (B-2) and control was quickly redeveloped, the DRL being increased to a maximum of 18 sec at *f*. At *g* the original correlation was reestablished. This change also produced a ratio breakthrough, but the loss of control was only temporary and original control was quickly redeveloped. At *h* the correlation was again reversed but this time without effect.

The breakdown in performance produced by the reversal of the stimulus-schedule correlation indicates that control was exercised by the visual stimuli. However, the ease with which reversals were effected suggests that control was exercised not only by the specific stimuli but also by the change in stimuli, green changing to red, and possibly by order of schedules, DRL followed by FR.

Chain FI FR: Developmental Procedures

A second chain schedule used to produce stimulus control was the chain FI FR. This schedule was programmed by pairing a green light with the FI and a red light with the FR. When the green light was present the *S* was reinforced on an FI with a change in stimuli, green to red light, and a change in schedules, FI to FR. Completion of the ratio resulted in the activation of the yellow light and the buzzer and the simultaneous delivery of a trinket. Following reinforcement, the cycle was repeated. The screen again became green, and the FI was again in effect. Thus, the programming of this schedule was identical to the chain DRL FR except for the first member.

No additional procedures. Only three of 12 *S*s were brought under schedule and stimulus control with chain FI FR schedules if they were begun initially on these schedules, and if no additional procedures were used. Records 1, 2, and 3 of Fig. 3 depict the development of stimulus control under these conditions. In this particular case the schedule was held at chain FI 1¼ FR 10 throughout the three sessions. The different rate patterns can be seen during the sixth excursion of Record 1. Fixed ratios were usually run off at a high constant rate and with little or no pausing once the red light had been produced. Fixed-interval patterns, on the other hand, show considerable variability. On some occasions postreinforcement pauses were very short so that many responses were emitted during the FIs. When acceleratory patterns occurred during the FIs, they were usually abrupt in nature. On a few occasions, however, more gradual accelerations occurred. Instances of these may be seen at *a* and *b* of Record 2.

Increasing size of FR. Records 1 through 5 of Fig. 4 also illustrate the development of stimulus control when an *S* was begun on this schedule without previous experience on another. Unlike the preceding *S*, however, this *S*'s performance was augmented by an additional procedure, namely, an increase in the size of the FR component. Records 1 and 2 show this *S*'s performance during his first and second sessions on chain FI 1¼ FR 10. Record 2 here resembles in many ways the behavior depicted in Record 3 of the previous figure.

The weak control developed during the second session was lost during the third. In an attempt to reduce the amount of responding during the FIs and thus reestablish both schedule and stimulus control, the FRs were increased to 20 during the third and fourth sessions. The records of these two sessions are not included. Record 3 of Fig. 4 is a record of the fifth session. The *S* was begun on a chain FI 1¼ FR 20. The FR was increased to 25 at *a* and to 30 at *b*. A similar procedure was carried out during the sixth session (Record 4), the FR being increased from 20 to 25 at *c* and to 30 at *d*. Because control developed so quickly, the FR component was begun and maintained at 20 during the seventh session (Record 5). Although FI responding was irregular in several places, stimulus control remained generally strong.

External clock added to the FI. Another technique used successfully to establish stimulus control with chain FI FR schedules entailed attaching an external clock to the FI component. The clock was added in the same manner as previously in the case of multiple schedules (Long, 1962). This procedure caused the translucent screen of the console to remain relatively dark (0.62 ml) and free of any detectable color during the first 20 to 25 sec of each interval. After that time the screen became increasingly bright, terminal luminance being 10.8 ml. After the fixed interval had timed out, a response changed the schedule to an FR and the screen from the then existing bright green to a bright red.

Most *S*s begun on chain FI FR schedules with a clock added to the FI were brought under schedule and stimulus control. This entailed responding at low constant rates or

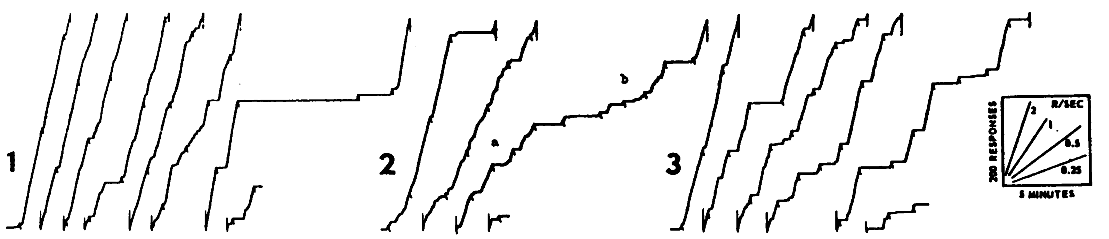

Fig. 3. The development of stimulus control with a chain FI FR schedule.

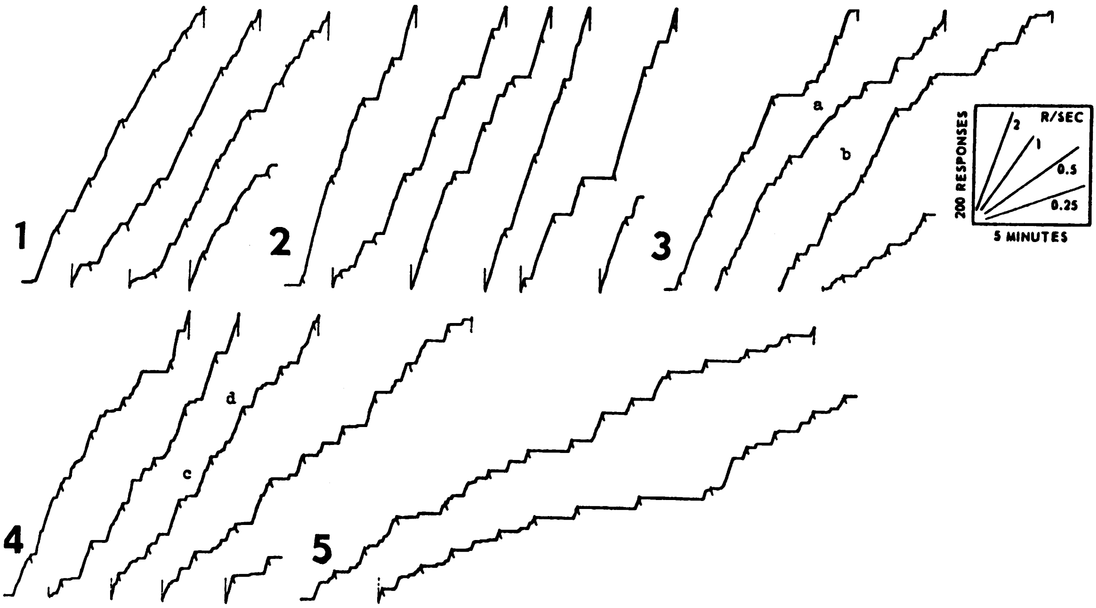

Fig. 4. The effect of increasing the size of the FR on the development of stimulus control with a chain FI FR schedule.

with abrupt acceleratory patterns in the presence of the clock correlated with the FI, and with a high constant rate in the presence of the red light correlated with the FR. Records A, B, and C of Fig. 5 show the development of such control in three *S*s during their first sessions on this schedule. Control developed more rapidly in *S* C who was run on a chain FI 1¼ FR 20. The other two *S*s were run on a chain FI 1¼ FR 15. Weakest control was developed in A. Control developed more slowly in the case of *S* B than *S* C, but its final level was equally strong.

A clock was sometimes added later if control had not been developed or if it had been developed and subsequently lost. Records 1, 2, and 3 of Fig. 6 depict a successful instance of the latter. Record 1 is that of an early session of an *S* on chain FI 1¼ FR 10 without an added clock. Control can be seen during the last three excursions. During the next session (Record 2) the previous fixed interval

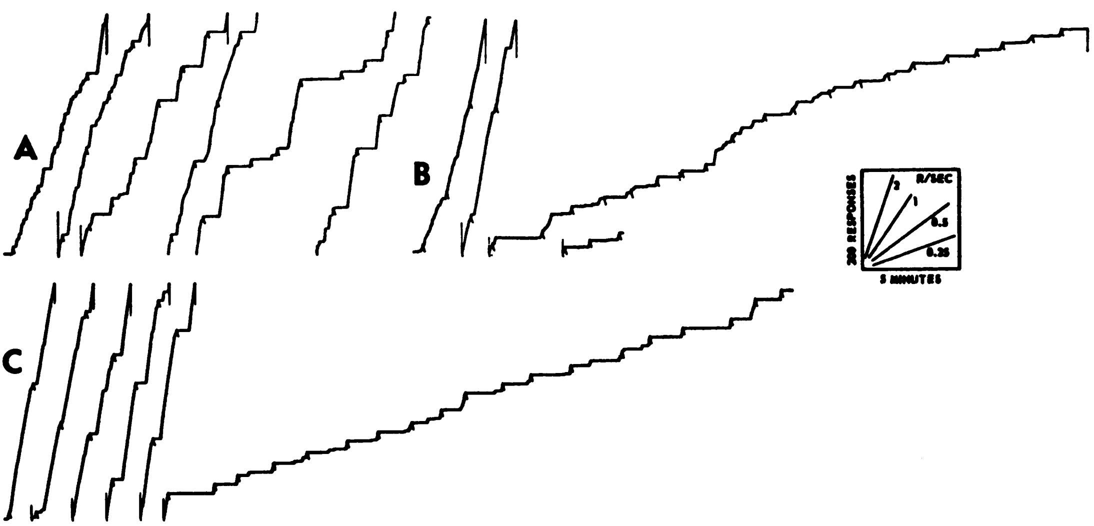

Fig. 5. First session records of three *S*s on chain FI FR schedules with an external clock added to the FI.

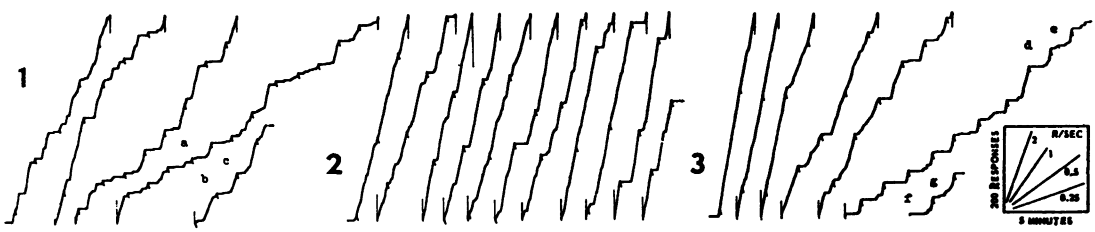

Fig. 6. The redevelopment of chain FI FR control by the later addition of an external clock to the FI.

control was lost. After two further sessions during which this control was not regained even though the FR was increased, the clock was added. Record 3 is a record of that session. The schedule throughout is chain FI 1¼ FR 30. Strong schedule and stimulus control can be seen in the last three excursions.

Attention is again called to the gradual acceleratory patterns produced by the FI component in this *S*. These patterns may be seen at *a*, *b*, and *c* of Record 1 and at *d*, *e*, *f*, and *g* of Record 3. Although such responding was by no means characteristic of all *S*s on chain FI FR schedules, more such FI scallops were seen in conjunction with chain FI FR schedules than with any other schedules thus far explored by the author.

Chain FI FR after chain DRO FR. In an earlier paper Bijou and Orlando (1961) described a technique for establishing mult FR ext control in retarded children. Subsequently, I employed the same technique with normal children (Long, 1962) and at that time also considered the schedule to be a multiple. Now, however, it is proposed that the schedule be considered a chain, specifically a chain DRO FR. The first member of this chain entails reinforcing behavior other than operating the manipulandum with a change in discriminative stimuli, *e.g.*, green to red light, and a change from a DRO to an FR. The FR is reinforced in the usual way, *i.e.*, by the yellow light, the sound of a buzzer, and the delivery of a trinket. One reason for the suggested change in terminology is to emphasize the fact that performance during the first member controls the appearance of later and perhaps different stimuli and schedules—a major characteristic of chain schedules. A second reason is to permit a later comparison of this procedure and its effects with a tandem schedule which closely resembles it.

In the present series of experiments chain DRO FR schedules were not studied in their own right but rather were employed as training procedures designed to augment the later development of schedule and stimulus control with a chain FI FR schedule. In this regard they were highly successful, 16 of the 20 *S*s previously exposed to chain DRO FR schedules later coming under stimulus control with chain FI FR schedules.

Records 1 through 5 of Fig. 7 illustrate the usual developmental sequence. Record 1 depicts this *S*'s last 475 responses on chain DRO FR. During the course of this excursion the DRO was increased from 12 to 24 sec, the FR being held constant at 10. At the beginning of the next session (Record 2) the schedule was changed to chain FI 1¼ FR 10. Schedule and stimulus control appeared almost immediately. The schedule was held at chain FI 1¼ FR 10 during the third session (Record 3), and strong control persisted. Early in the fourth session the FR component was increased to 20 (*b* of Record 4). It was further increased to 30, 35, and finally 40 during the next session (*g*, *h*, and *i* of Record 5). Strong control was manifested during both of these sessions. Typically, this *S*, like almost all others who received this sequence of training, paused for the programmed duration of the FI components, then in the presence of the red light ran off the ratios quickly. Again, a few *S*s demonstrated well developed scallops during the FIs, and instances of these can be seen at *a*, *c*, *d*, and *e* of Record 4 and at *f* and *j* of Record 5.

In six of those *S*s begun on a chain DRO FR the development of stimulus control with chain FI FR schedules followed a different sequence. One instance of these variations is shown in Records 1 through 4 of Fig. 8. Record 1 shows the *S*'s last 400 responses on a chain DRO FR. At the beginning of the next session (Record 2) the schedule was switched to a chain FI 1¼ FR 10. Unlike the record of the previous *S* this record shows little or no

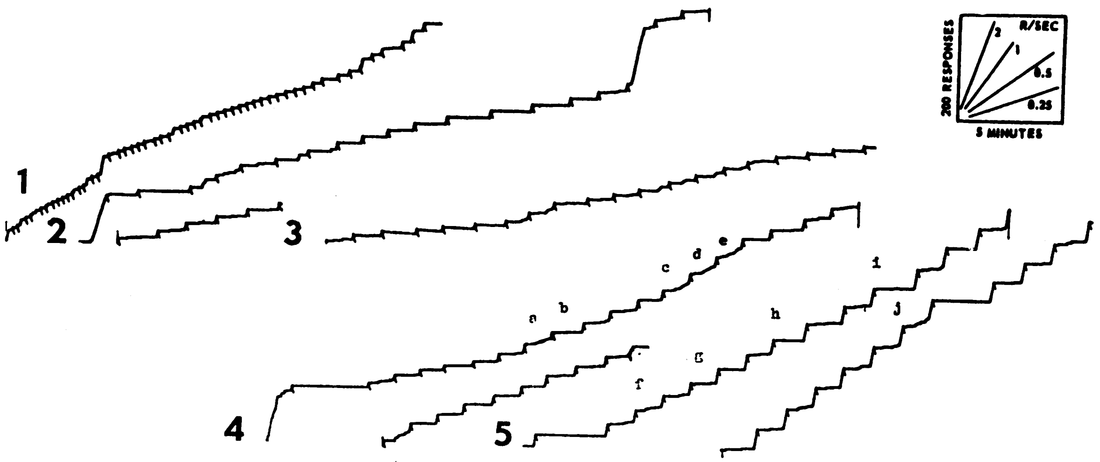

Fig. 7. The typical effect of prior chain DRO FR scheduling on the subsequent development of stimulus control with chain FI FR schedules.

control principally because of the high rate during the fixed-interval components. During the following session (Record 3) the FR was increased to 15 at *a* and to 20 at *b*. These increases produced almost immediate control. Both schedule and stimulus control continued to be relatively strong during the fourth session (Record 4), further increases in the FR component from 20 to 25 at *c*, to 30 at *d*, and to 35 at *e* having little effect.

Why such variant developmental sequences occurred is not entirely clear. One possibility is that in many cases the final value of the FR component of the chain DRO FR schedules was relatively larger than the initial size of the FR component of the chain FI FR schedules. A second possibility is that the absolute rather than the relative size of the FR component of the chain FI FR was too small for some *S*s. In an earlier section of this paper (see Fig. 4) data were presented to show that chain FI FR control could be strengthened sometimes by increasing the size of the FR component. Further support for this hypothesis comes from Records 1 and 2 of Fig. 9. This *S* was begun on a chain DRO FR (Record 1). In the course of the session the DRO component was increased up to 24 sec, but the FR was held constant at 10. At *a* the schedule was changed to chain FI 1¼ FR 10. Control was partially lost as responding during the FI component rapidly increased. The FR component was then made larger than it had been during the chain DRO FR training. Specifically, it was increased to 15 at *b* and to 20 at *c*. These increases quickly led to stronger FI control. Record 2, *S*'s third session, shows the final level of control developed in this *S* with the chain FI 1¼ FR 20.

The most powerful technique for establishing control with chain FI FR schedules entailed the use of large FRs both with the preceding chain DRO FR and with the chain FI FR which followed. The six *S*s on whom this procedure was employed were begun on FR 10. The FR value was then quickly increased to a maximum value of 45 or 50, and as soon as FR control became strong, the chain DRO FR was introduced. During this second phase the FR was kept at its terminal value,

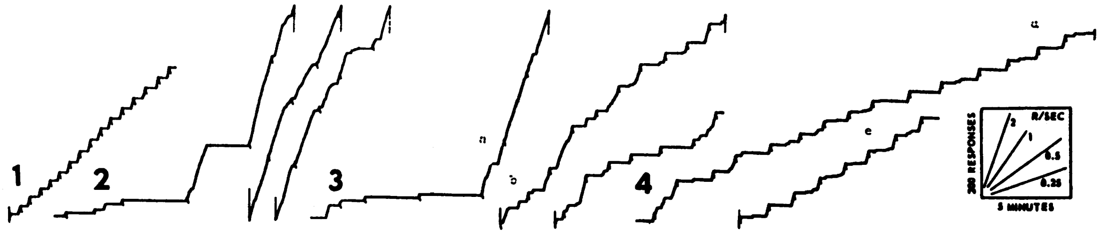

Fig. 8. An atypical sequence of stimulus-control development with a chain FI FR schedule after chain DRO FR scheduling.

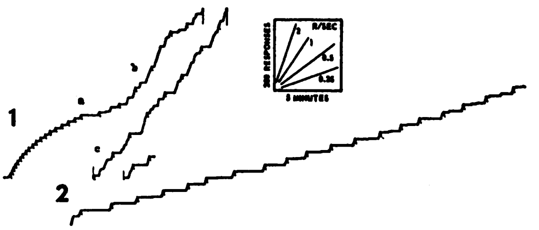

Fig. 9. The effect of increasing the size of the FR component on the development of chain FI FR control in an *S* previously reinforced on a chain DRO FR schedule.

and the DRO was gradually increased from two up to a value of approximately 20 sec. At the beginning of the next session control with the chain DRO FR was quickly reestablished, and following this the schedule was changed to chain FI 1¼ FR 50.

Records A-1 and A-2, and B-1 and B-2 of Fig. 10 depict the developmental sequences of two *S*s. The initial FR for *S* A was increased from 10 to 50. At *a* the schedule was shifted to chain DRO 2 FR 50. The DRO was then gradually increased to a maximum of 22 sec. During the following session (A-2) the schedule was gradually increased from DRO 4 FR 50 up to DRO 30 FR 50 at *b*. At *c* the schedule was shifted to chain FI 1¼ FR 50. Because of the previous contingencies of the chain DRO FR, the first FI pause was much longer than the programmed length of the FI. The *S* ultimately responded, however, changing the green light to red and then ran off the FR 50. Both schedule and stimulus control were very strong in the remainder of the session.

Records B-1 and B-2 resemble those records just discussed, though the FI control was somewhat less strong. The FR was increased to 45 before the shift to chain DRO FR at *d*, and following this, the DRO component was gradually lengthened to a maximum of 30 sec at *e*. During the following session the FR component was held at 45 while the DRO was gradually increased to 32 sec. At *f* the schedule was changed to chain FI 1¼ FR 45, and control again appeared almost immediately.

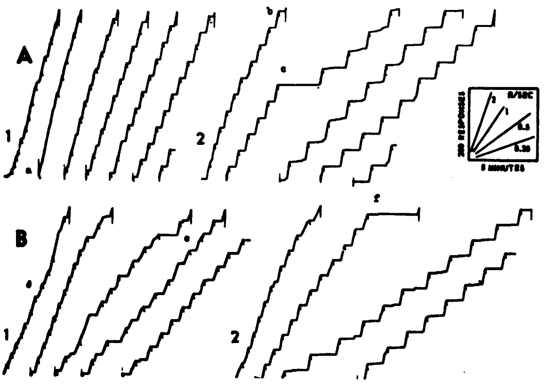

Fig. 10. Strong chain FI FR control following chain DRO FR scheduling with large FR components in both schedules.

The rate patterns seen here are representative of those produced in all *S*s. Thus, most *S*s paused for the duration of the FI then, after producing the red light, ran off the FR at a high constant rate. Occasionally an *S* partially ran through an FI or split an FR, but such deviations were rare even when earlier chain DRO FR control was weak.

Chain FI FR after chain DRL FR. The development of schedule and stimulus control with chain FI FR schedules was often augmented by the earlier establishment of such control by chain DRL FR schedules before shifting to the chain FI FR. Records 1, 2, and 3 of Fig. 11 illustrate such a developmental sequence. During the session depicted in Record 1 the DRL was increased from 4 to 32 sec. At *a* the schedule was changed from chain DRL 32 FR 10 to chain FI 1¼ FR 10. During the following session the FR component was increased to 15 (*b*, Record 2). The schedule was kept at this value during the third session. Discriminably different rate patterns can be seen developing almost from the time that the chain FI FR schedule was put into effect.

Strength of stimulus control was assessed in two ways. These entailed reversing the stimulus-schedule correlation and changing the chain FI FR to a tand FI FR.

Reversing stimulus-schedule correlation. Records 1, 2, and 3 of Fig. 12 illustrate the effect of this reversal on a chain FI 1¼ FR 10. At the beginning of the session depicted in Record 1 the FI component was paired with a green light, and the FR with a red. At *a* the stimuli were reversed, the schedules being left in their original order. This produced a burst of approximately 60 responses followed by a 20-min period of very low rate responding in the presence of both stimuli. The reversed correlation was left in effect during the following session (Record 2), and the rate patterns became more similar to those observed before the reversal. The original cor-

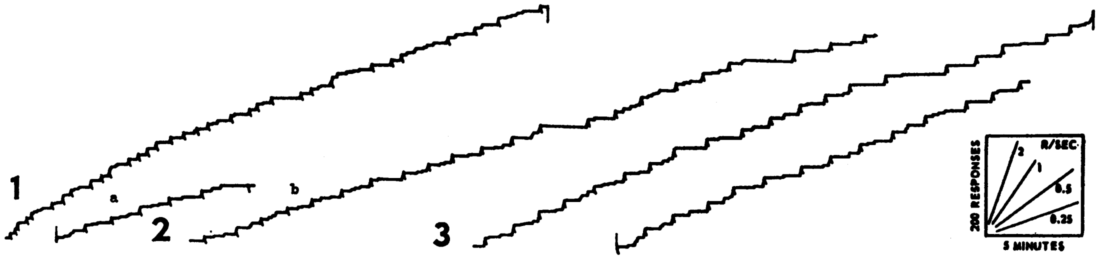

Fig. 11. The development of stimulus control with a chain FI FR schedule after previous chain DRL FR scheduling.

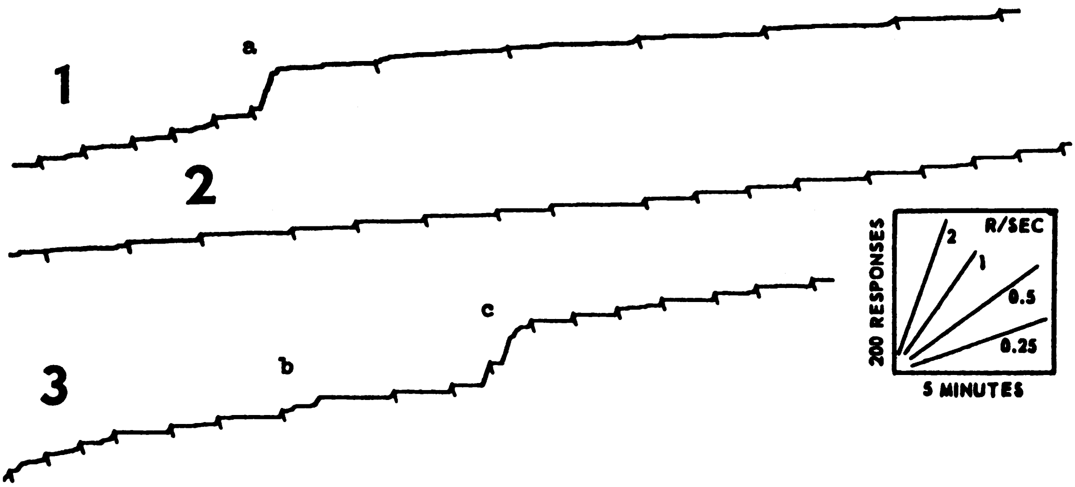

Fig. 12. The effect of reversing the stimulus-schedule correlation on stimulus control maintained by a chain FI 1¼ FR 10.

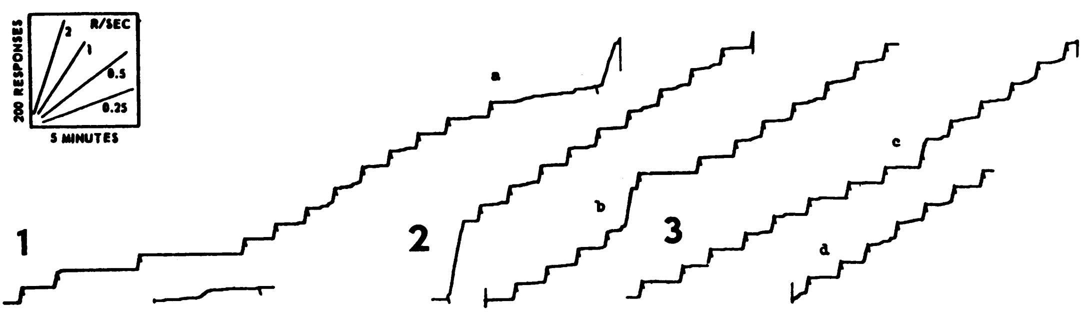

Fig. 13. The effect of reversing the stimulus-schedule correlation on stimulus control maintained by a chain FI 1¼ FR 30.

relation was reestablished during the next session (at *b* of Record 3). This had the effect of producing a small burst of responses, but the main effect of the change was to suppress responding temporarily. After a ratio break-through occurred (at *c*), strong schedule and stimulus control was again developed.

Performance was often less disrupted by stimulus reversal if the FR component was relatively large. The records of Fig. 13 and 14 illustrate this. Records 1, 2, and 3 of Fig. 13 are of an *S* on chain FI 1¼ FR 30. At *a* of Record 1 the correlation was reversed. Again the rate was lowered. The reversed correlation was kept in effect during the next session, and the original rate patterns were quickly redeveloped in the presence of the reversed stimuli. At *b* of Record 2 the original correlation was reestablished. This caused the S to start the terminal run of the first FI too soon and thus to emit too many responses. After reinforcement S paused well beyond the programmed duration of the next interval, but then ran off the ratio without interruption. Strong schedule and stimulus control were then maintained throughout the remainder of the session. At *c* of Record 3 (the following session) the correlation was again reversed. This produced a brief ratio burst during the FI component, but otherwise no loss of control occurred. At *d* the original correlation was reestablished for a second time. This time it had no demonstrable effect on the patterns of responding.

Figure 14 depicts the performance on an S during one session on chain FI 1¼ FR 50. At *a* the correlation was reversed. This produced an immediate burst of 200 responses, but control quickly redeveloped. At *b* the original correlation was reestablished. This had little or no effect on the current strength of control.

These records suggest that stimulus control here, as in the case of chain DRL FR schedules, was dependent in part on the specific visual stimuli, in part on change of stimuli, and in part on the order of the schedules. Reversal of the stimulus-schedule correlation here disrupted performance in approximately the same way as it did with the chain DRL FR correlation. It produced much less disruptive effects, however, than it had in most cases where mult FI FR schedules were used and thus where the schedule order was much less regular (Long, 1962). The finding that continued reversals of stimulus-schedule correlation had less and less effect suggests that the control exercised by stimulus change and order of schedules can be strengthened in the same way as that mediated by specific stimuli.

Shift to tand FI FR. To determine further what stimulus variables were controlling performance several Ss were changed from chain FI FR schedules to tand FI FR schedules. Under this schedule condition the stimulus screen remained the same color during both schedule components. In half the cases the screen was green, the stimulus color previously paired with the FI member of the chain. Records 1, 2, 3, and 4 of Fig. 15 illustrate the effects of this manipulation. Record 1 depicts the performance of this S's ninth session on chain FI 1¼ FR 25. The schedule was maintained at this value during the first six reinforcements of the next session (Record 2). At *a* the schedule was changed to tand FI 1¼ FR 10. This change greatly reduced overall rate, and in spite of the fact that responses were reinforced in the presence of the green light the rate remained very low. It remained equally low during the first two thirds of the next session. At *b* of Record 3 the tand FI 1¼ FR 10 was changed to a chain FI 1¼ FR 10. This quickly increased rate, and at *c* the FR member was increased to 20. The schedule was kept at this value during the next session and both schedule and stimulus control quickly redeveloped.

These records suggest that the control exercised by a particular visual stimulus, *i.e.*, the green light paired with the FI, was stronger than that exercised by schedule order if stimulus change was also absent. Such was not found to be the case, however, if the change from chain to tandem entailed using the red light, the light previously paired with the FR. Instead, after a relatively brief period of high

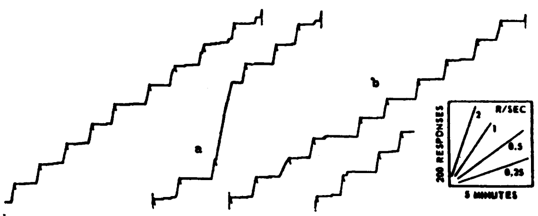

Fig. 14. The effect of reversing the stimulus-schedule correlation on the stimulus control maintained by a chain FI 1¼ FR 50.

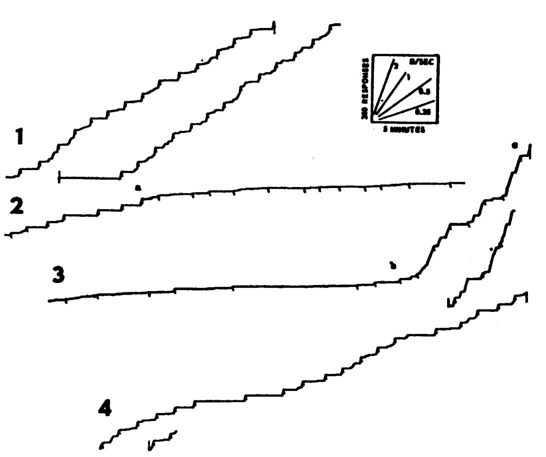

Fig. 15. The effect of changing from a chain FI FR to a tand FI FR where the stimulus accompanying the tandem is identical to that which previously accompanied the FI component of the chain.

rate responding, most S's came to demonstrate rate patterns which had many characteristics of those previously produced by the chain schedules, *e.g.*, low rates or perhaps abrupt acceleratory patterns after reinforcement followed in turn by high constant rates. The record in Fig. 16 is typical of such outcomes. The record is of this S's fifth session on chain FI FR schedules. After performance had stabilized, the schedule was changed from chain FI 1¼ FR 20 to tand FI 1¼ FR 20 (at the arrow). During the next four reinforcements the terminal rate of the FI was reached too soon, and thus count was three to five times as great as it had been when the chain was in effect. Following this, rate patterns like those produced by the chain alternated with those of greater count, with the general trend being in the direction of count reduction and the resumption of the chain-like patterns. Records such as this clearly add further support to the hypothesis that schedule order as well as specific visual stimuli or change of stimuli can operate as a controller of rate patterns.

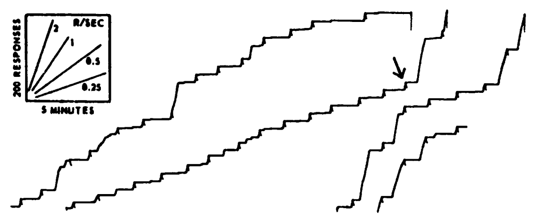

Fig. 16. The effect of changing from a chain FI FR to a tand FI FR where the stimulus accompanying the tandem is identical to that which previously accompanied the FR component of the chain.

RESULTS: TANDEM SCHEDULES

In the preceding section evidence was obtained for the hypothesis that schedule order could operate as a controller of rate patterns. This was demonstrated by first developing control with a chained schedule and then shifting to a tandem schedule having the same values. The question which immediately arises is can such control be developed and maintained with a tandem schedule if it has not been previously developed with a chained schedule? To answer this, Ss were begun initially on tandem schedules.

Tandem FI FR. Developmental Procedures

No additional procedures. The only tandem schedule studied in detail was the tand FI FR. Of those Ss begun on this schedule none generated rate patterns which would suggest strong stimulus control based on schedule order. Records 1 and 2 of Fig. 17 depict the performance of perhaps the most strongly controlled S during its third and fourth sessions on a tand FI 1¼ FR 10. This S usually paused briefly after reinforcement and then began responding at its terminal rate. On some occasions, however, S ran through the FI component with no initial pausing. Fixed ratio rates were usually the same as terminal FI rates. Inasmuch as no tand FI FR record showed schedule or stimulus control comparable to that shown in the last two excursions of Fig. 16, it was concluded that if schedule order were to operate as a controller of rate patterns, additional procedures had to be employed to facilitate the development of this control.

Addition of clock to FI. In an attempt to produce schedule and stimulus control, a clock was added to the FI component in the same way as in multiple and chained schedules. Completion of the interval by the S changed the schedule from FI to FR, but the screen remained the same bright green that it had been during the final seconds of the FI. It might be argued that this schedule is no longer a tandem because of the differences between the stimuli accompanying the FIs and the FRs. On the other hand it is not like the usual chain where completion of the first schedule is signaled by a stimulus change. It might best be seen as a transition between the chain and the tandem with the expectation that stimulus control might be somewhere between the two.

Records A-1, A-2, and A-3 and B-1, B-2, and B-3 of Fig. 18 depict the effect of this schedule

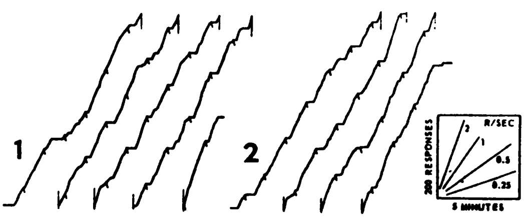

Fig. 17. The records of two consecutive sessions on a tand FI 1¼ FR 10.

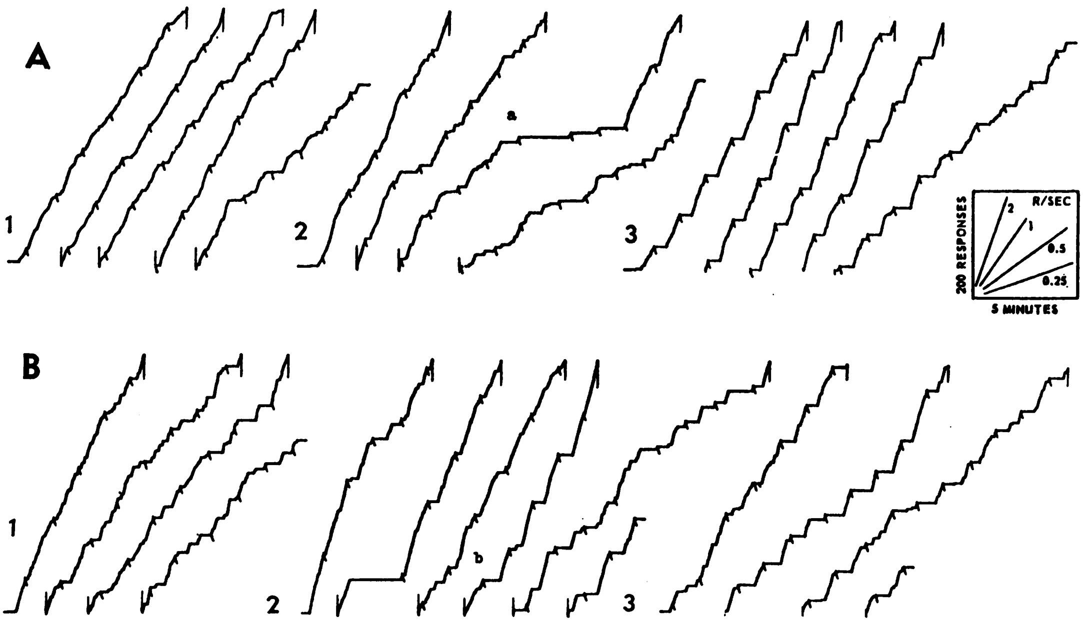

Fig. 18. The performance of two *S*s on tand FI FR schedules with an external clock attached to the FI.

on the performance of two *S*s. Record A-1 is of this *S*'s second session on tand FI 1¼ FR 10. The clock was introduced during the next session at *a* of Record A-2. This produced some instances of prolonged, post-reinforcement pausing during the FI components but no regular rate patterns. However, well defined, repeatable response patterns were produced from the beginning of the next session (Record A-3). A similar change was made in the case of a second *S*. The clock in this case was added during the third session (at *b* of Record B-2). It was left in effect during the following session (Record B-3). As in the case of the previous *S*, addition of the clock almost immediately produced repeatable rate patterns.

Addition of the clock always had the effect seen in the previous records. While longer than those seen in Fig. 16 the post-reinforcement pauses here were not as long as those usually produced by the chain FI FR with an external clock. Similarly, FRs usually were run off at a high constant rate, but more instances of splitting or generally irregular responding were seen here than in the case of comparable chains.

Tandem FI FR after tand DRO FR. A second technique which was helpful in the development of schedule and perhaps stimulus control by means of tand FI FR schedules was to precede their use with tand DRO FR schedules. The tand DRO FR was identical to the chain DRO FR except for the absence of the stimulus change accompanying the change from DRO to FR, and the training sequence paralleled that used when chain DRO FR schedules were made to precede chain FI FR schedules.

Records A-1 and A-2 of Fig. 19 depict a typical sequence resulting from the use of this procedure. This *S* was begun on an FR which was increased from 10 to 40 as control developed. At *a* of Record 1 the schedule was changed to a tand DRO 4 FR 40. During the remainder of the session the DRO component was gradually increased to a maximum of 24 sec, the FR remaining at 40.

During the first 10 min of the next session (A-2) the schedule was increased from tand DRO 6 FR 40 to tand DRO 24 FR 40, and at *b* it was changed to tand FI 1¼ FR 40. Regular rate patterns appeared almost immediately. Long post-reinforcement pauses followed by abrupt increases in rate occurred during the FI components. Fixed ratio rates were always high and constant. These final data suggest that with appropriate procedures it is possible to produce and maintain differential rates of responding closely resembling those produced by chained schedules but which are correlated only with schedule order.

DISCUSSION

The data presented here were obtained from *Ss* ranging from 4 to 7 yr in age. No differences in sensitivity to schedule contingencies based on chronological age were observed. It should be noted, however, that all *Ss* participated on a volunteer basis, and as a consequence fewer 4-yr olds than 6-yr olds participated. Had all children been forced to participate an age-schedule sensitivity relationship might have been observed.

No comparison of the chain DRL FR records with those generated by infrahuman organisms is possible because of the lack of such data. Chain FI FR record comparisons are possible, however, and the records obtained here with chain FI FR schedules closely resemble those previously obtained with other organisms (Ferster and Skinner, 1957). Similarly, the discovery that increasing the size of the FR component reduces the amount of responding during the FI has been reported previously with other organisms (Hanson and Witoslawski, 1959).

The major difference between the present experiments on chain FI FR schedules and previous ones lies in the techniques which were required to produce stimulus control. Most children begun on chain FI FR schedules never showed stimulus control, *i.e.*, never showed discriminably different rate patterns in the presence of the different colored lights. In large measure this was due to the fact that repeatable rate patterns were not developed and maintained by the component schedules making up the chain. Throughout the paper this type of control has been referred to as schedule control to differentiate it from the control exercised by the exteroceptive stimuli.

Why chain FI FR schedules failed to produce schedule and stimulus control in so many children and why the additional procedures were helpful in remedying this cannot be answered with great certainty. One possibility is that the DRO and DRL contingencies contrasted sharply enough with the FR contingencies to produce repeatable rate patterns which differed from those produced by the FRs. In addition, these contingencies were so strong that many of the behavioral characteristics which they produced, *e.g.*, postreinforcement pausing, persisted even after the weaker controlling FI schedules were substituted. Such an outcome could make possible the demonstration of exteroceptive stimulus control with chain FI FR schedules.

A second possible answer is that schedule control did not develop because stimulus control had not. The explanation for this is that the children did not carefully observe the programmed stimuli, their own behavior, or the correlation between the two. Prior scheduling with chain DRO FR and chain DRL FR schedules or the attaching of an external clock to the FI component of the chain FI FR schedules either compelled or greatly augmented such observing behavior. It is apparent that additional research will be needed before the final answer is obtained.

Inasmuch as the present research was exploratory rather than parametric in nature, it is not possible to say precisely how much stimulus control was exercised by various aspects of the environment. The specific stimuli correlated with the schedules obviously exercised greatest control. However, because the chain used here always alternated stimuli and schedules, stimulus change and

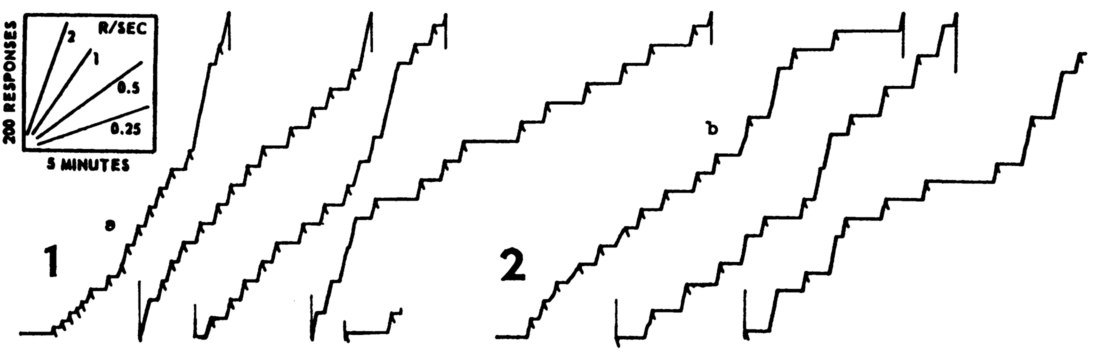

Fig. 19. The development of tand FI FR control after tand DRO FR scheduling.

order of schedules also played controlling roles.

That stimulus change can control rate patterns is not too surprising. How schedule order comes to exercise stimulus control, however, is more difficult to explain. Experimental results at this point suggest that it does this through the child's own behavior which takes on discriminative properties. Thus the schedule order FI followed by FR is translated into low rate followed by high rate or perhaps some other kind of behavior followed by key pushing. Chain DRO FR and chain DRL FR schedules force such a sequence and correlate it with external stimuli. The tand DRO FR schedule forces the same behavioral sequence but in the absence of changing external stimuli. It is this sequence and its accompanying behaviorally-produced stimuli which permit a tand FI FR schedule to exercise chain-like control if it is preceded by a tand DRO FR.

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