SINGLE AND MULTIPLE SCHEDULES OF REINFORCEMENT IN DEVELOPMENTALLY RETARDED CHILDREN[1,2]

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Free-operant conditioning methods are being used with increasing frequency in a wide range of research applications with human subjects. Although some of the schedules of reinforcement which are of central importance in this kind of research have been systematically evaluated with infrahuman organisms (Ferster & Skinner, 1957), as yet few studies bear directly on questions of generality, variability, and special effects of schedule control in human *S*s (Bijou, 1958; Ellis, Barnett, & Pryer, 1960; Green, Sanders, & Equier, 1959; Holland, 1957; Holland, 1958; Long, Hammack, May, & Campbell, 1958). Aside from academic issues involved in assumptions that infrahuman data provide sufficient bases for application in human behavior (Beach, 1960) and the need for genuine comparative and developmental data, practical research problems arise. Typically, extensive "trying out" of schedule types and values is necessary to find appropriate rate, pause distribution, resistance to extinction, and other features of free-operant behavior for studies using human *S*s. The results of these time-consuming preliminary investigations are potentially valuable for other researchers because they provide empirical foundation for the selection of schedules with maximum sensitivity and control.

The purpose of the present paper is to show characteristic performances under four basic schedules (VI, FI, VR, and FR) and two multiple schedules (mult VR ext and mult CRF ext) in human *S*s, and to illustrate *some* of the range and variability of these features in a population of institutionalized developmentally retarded children.[3] However, we did not attempt to demonstrate the full range of possible schedule values or limiting conditions and thresholds. Examples are from schedules that have proven useful in the study of retarded children.

METHOD

Subjects

The *S*s were 46 institutionalized retarded children ranging in CA from 9 to 21 and in IQ from 23 to 64. They were in residence from 1 to 16 years. Diagnostic categories included mongoloid, epileptic, familial, and others; and all were ambulatory. They came on request to the reception room of the laboratory from residence halls, classrooms, or work assignments.

All *S*s had previously taken part in a study exploring a technique for the rapid establishment of multiple-schedule performance in the same experimental situation. Instructions, types of reinforcements, intersession intervals, and other conditions were the same for all *S*s.

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[3]The term *developmentally* retarded is used in place of such terms as "feeble-minded" and "mentally deficient." It is preferred because it is neutral with respect to etiology and avoids mentalistic implications. Furthermore, the term is descriptive and normative as noted by Cameron and Magaret (1951).

Apparatus

The *S*s were placed by themselves in an 8- by 10-foot room furnished with two chairs and a small table. The table, fixed to the wall next to a one-way observation window, contained a sturdy wooden response box and a chute for receiving reinforcers dispensed by a Gerbrands Universal Feeder mounted on the other side of the wall. The 12- by 16- by 12-inch response box was equipped with a 3-inch metal press-to-manipulate lever (handle grip for the squeezer of an O-Cedar sponge mop). This lever had a 4-inch vertical travel, and about a 150-gram pressure was necessary to operate it. Two colored jewel lights on the same front panel of the box and a buzzer inside could be used for various stimulus events.

Automatic equipment in an adjoining room provided remote control and recording operations. This consisted of electrical circuits, timers, tape-programmers, and cumulative recorders similar to those used with infrahuman *S*s (Ferster & Skinner, 1957). A 300-watt frosted bulb in the center of the ceiling provided general illumination (in addition to sunlight from an airshaft-facing window), while a smaller bulb high over the response box served as a "bridge" by going out for 3 seconds following every reinforcement delivered *via* the chute.

The reinforcers were a mixture of commercially produced candies such as Hersheyettes, candy corn, M & M's, and mints. For most *S*s, these candies were a highly coveted reward. (Many *S*s traded candy to other children for pencils and small toys.)

Procedure

Since all of the *S*s had had previous experience in the situation, each session was preceded by minimal instructions: "Now it is your turn to get some candy. I'll be back when it is time to leave." Original instructions were: "Now it is your turn to get some of these (*E* shows a handful of candy). Come with me (ushers into the experimental room). Sit in this chair (in front of the apparatus). Now watch me; I'll show you how we get candy here (*E* presses lever five times at the rate of 2 per second, and the fifth response is reinforced). See? Here's candy for you. Now you do it. You get candy." (Then *E* leaves the room after *S* makes five independent responses and gets a reinforcement.) All sessions were terminated with, "That's all for today. Go and sit in the waiting room."

Sessions were 15 to 60 minutes, depending on the rate that reinforcers were earned, and typically were scheduled on a two-a-week basis. For those *S*s who were shifted from one schedule to another, a criterion of no apparent change for two successive sessions was used before shift (i.e., essentially no change in over-all rate, number of reinforcers earned, duration and distribution of pauses, etc.).

Records were obtained on a Gerbrands Cumulative Recorder with paper speeds of 30 and 60 centimeters per hour and a reset number of 400 responses. With multiple schedules, type and duration of discriminative stimuli were recorded by a special events pen directly under the cumulative-response curve.

RESULTS AND DISCUSSION

Figures 1 through 5 show the cumulative-response curves of selected *S*s under a variety of schedules. These illustrate *representative* behaviors, and, in most of them, acquisition and transition stages have been omitted. When feasible and appropriate, segments have been collapsed on the abscissa to conserve space. (These may be identified by the absence of "reset" lines.) Each record is accompanied by *S* numbers (S-1, S-2, etc.), sessions numbers consecutive for each *S*, and schedules.

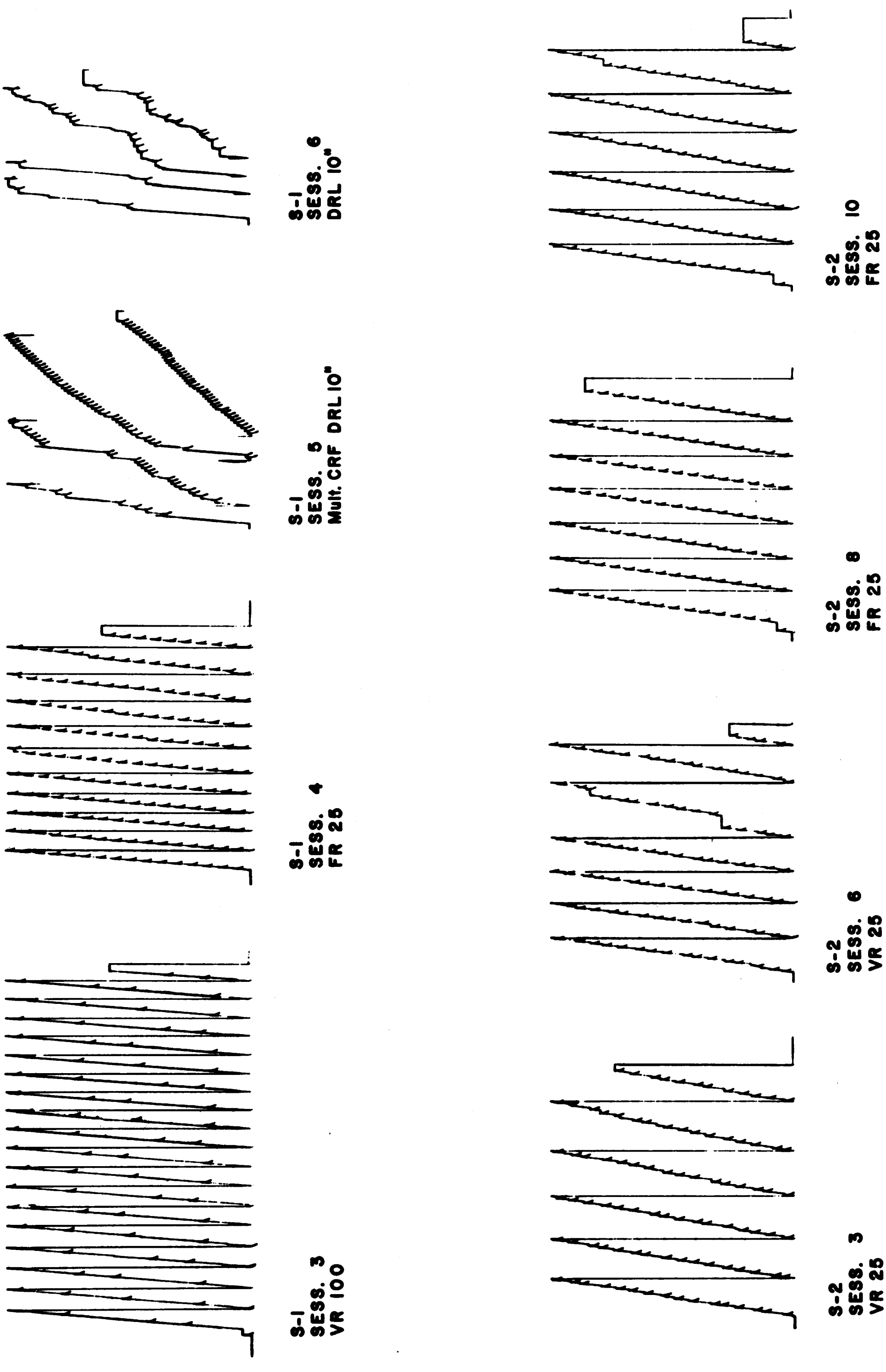

Figure 1. Cumulative records showing VR performances and shifts to DRL and FR. Each session is identified by *S* number, session number, and schedule.

In Fig. 1 through 4, the paper speed of the recorder was 30 centimeters per hour. In Fig. 5, it was 30 centimeters per hour for *S*s 11, 12, and 13, but 60 centimeters per hour for *S*s 14 and 15.

VR

Like infrahuman *S*s, retarded *S*s produce high rates of responding under VR which are roughly proportional to the size of the ratio, while pauses are infrequent, short, and random with respect to time of reinforcement. Also, these characteristics appear to be rather resistant to change with shift of schedule.

These effects are illustrated in Fig. 1. After training on VR 100 (range 40 to 160), S-1 developed a very high rate with practically no pausing (Session 3). A shift to FR 25 (Session 4) did not result in any discriminable changes in this performance, although two DRL schedules (mult DRL 10 seconds in Session 5 and DRL 10 seconds in Session 6) brought the rate down somewhat. A comparatively lower rate was developed and maintained in S-2 (Sessions 3 to 6) on VR 25 (range 15 to 35). Upon being shifted to FR 25 in Session 7, only slight fixed-ratio-like postreinforcement pauses emerged. These are shown in Sessions 8 and 10.

FR

The FR behavior is similar to that produced under VR in that high stable rates are common and higher rates are associated with lower (more responses per reinforcement) ratios; but pause distribution and durations are frequently different. Pauses (of greater duration than those associated with "consumatory" behavior) follow reinforcements, and the frequency of these pauses decreases as the ratio becomes lower.

The relationship between ratio size and rate can be seen in Fig. 2. Subject S-3 shows a rate increase when shifted from FR 10 (Sessions 3 and 6) to FR 25 (Sessions 8 and 10), approaching the high rate exhibited by S-4 under FR 25 (Sessions 6, 9, and 11) and VR 25 (Session 7). The temporary disturbance in postreinforcement pausing when S-3 was shifted from FR 10 to FR 25 illustrates schedule control (e.g., the short "runs" in the initial part of Session 8 are appropriate to the smaller ratio), as does the later shift to VR 25, in which an uneven rate and irregular pause distribution become manifest.

The records of S-4 in Fig. 2 represent a typical pattern on FR in which pauses do not invariably occur after every reinforcement, but occur *only* after reinforcement (Session 6). After a shift to VR 25 (Session 7), accompanied by an increase in rate and decrease in pause frequency, extensive training (4 sessions) on FR 25 was necessary to return behavior to near the original FR pattern (Session 11).

Some *S*s (not illustrated) adopt stable high rates with no discernible pausing under FR. These *S*s tend to continue responding at undiminished rates even in extinction conditions, suggesting that some motivational factor may be involved. This observation and the interpretation are consistent with findings reported by Ellis *et al.* (1960).

VI

The VI performances are almost identical to those generated under VR of an equivalent value. If there are any reliable differences, they are probably in greater "grain" and perhaps greater incidence of essentially random (with respect to time of reinforcement) pauses in VI.

Figure 3 shows a typical VI 0.5 (range 10 to 50 seconds) performance. A gradual increase in rate and decrease in pause frequency is apparent over sessions (Sessions 2 to 4). These effects carry over into FI 0.5 (Sessions 6 and 7) and even into DRL 0.5 (Session 8), in which

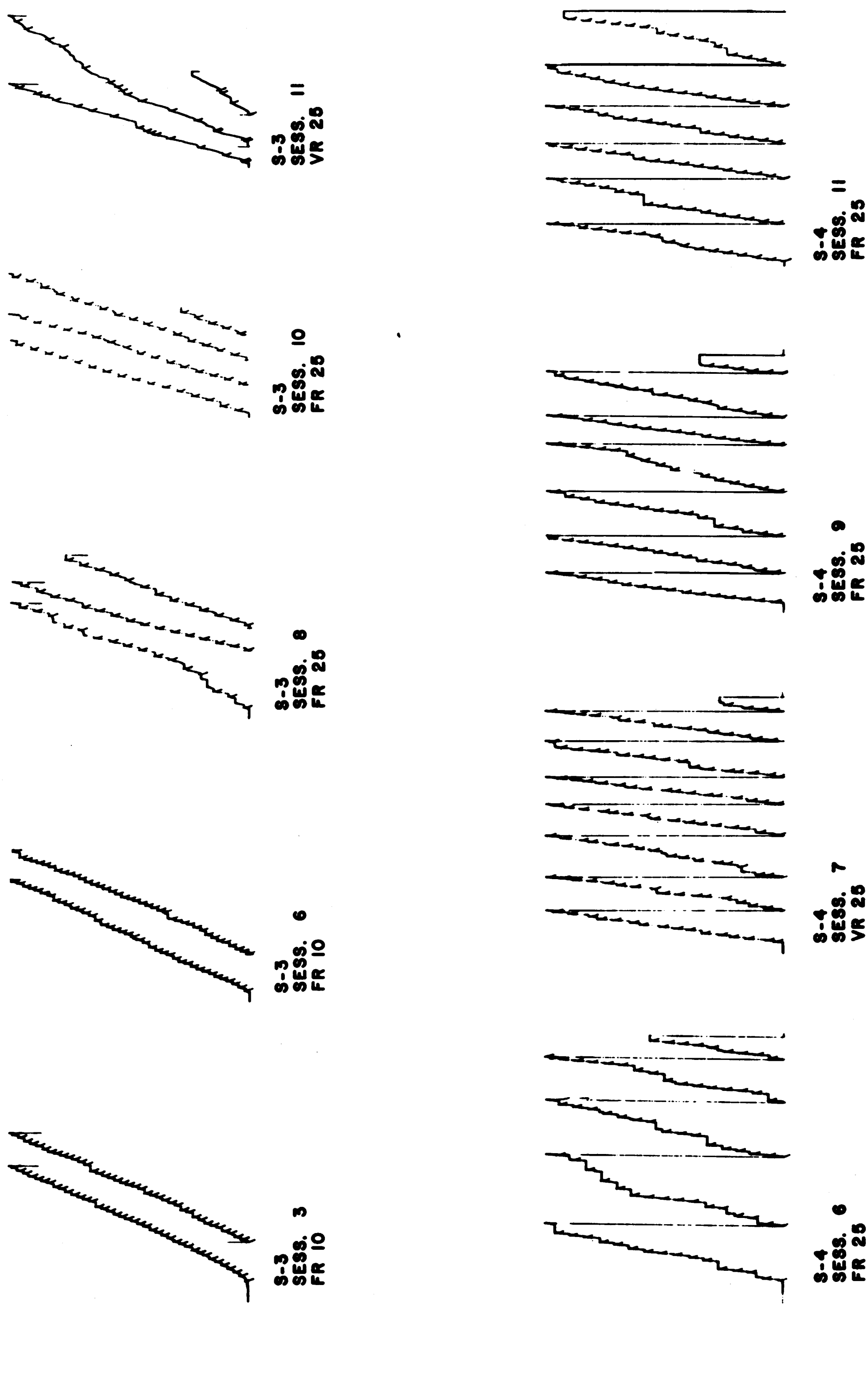

Figure 2. Cumulative records showing FR performances and shifts to larger ratios and VR.

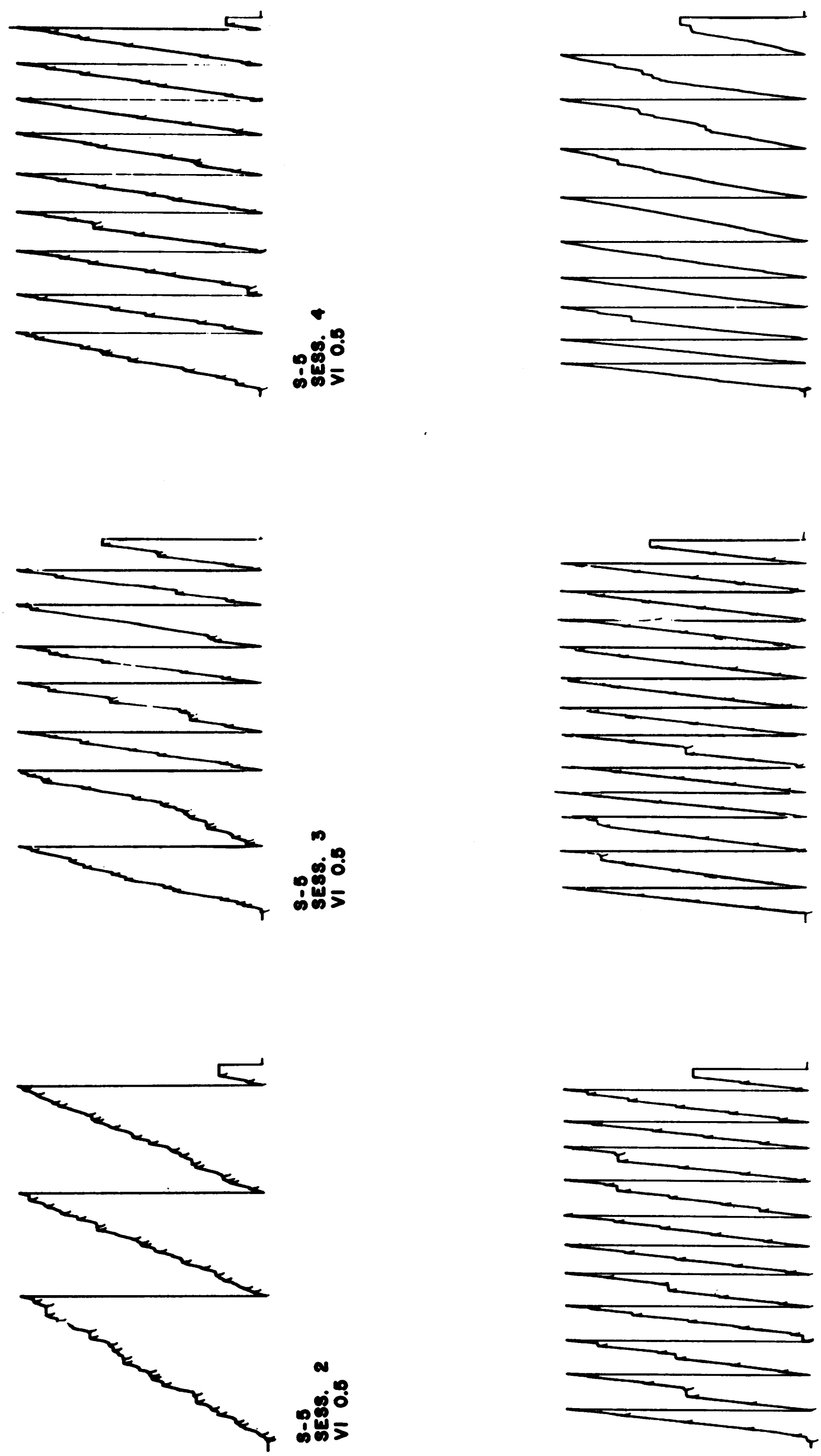

Figure 3. Records of a single *S* showing VI schedule control and resistance to change under FI and DRL.

no reinforcements were earned. This record illustrates the high resistance to schedule shift produced by VI, and is fairly typical of a wide range of interval values.

FI

Of the four basic types of schedules, the FI produces the greatest diversity of behaviors in developmentally retarded children. By and large, individual *S*s react to FI schedules in consistent ways, but individual differences are large, varying from "run-away" rates similar to those produced by VI schedules to low-rate "pacing." Scalloping is infrequent, although those *S*s who scallop do so consistently. Some medium rates with uneven patterns and high grain are also produced. With extended training, these *S*s usually come under schedule control and adopt low rates, most of them also producing an occasional scallop.

Figure 4 shows the records of *S*s under FI schedules. Subjects S-6 and S-7 are typical examples of low-rate solutions for FI 1 with only occasional scallops (Sessions 2 to 5). These *S*s were shifted to FR 15 (Session 6) to estimate resistance to schedule change. Neither *S* showed rate increase. They were then given an "increasing-ratio" schedule (beginning in Session 7), in which the number of unreinforced responses between reinforced responses is gradually increased (i.e., ratio is gradually increased from 1 : 1 to 1 : 15). Subject S-6 adopted a typical FR pattern on the final schedule, but S-7 continued the original low rate appropriate to the FI 1 schedule.

Subject S-8 in Fig. 4 is an example of the *S*s who give "scalloping" patterns on a variety of FI schedules. Although only final stages on each schedule are shown, other records appeared very much the same except for short periods immediately following the shifts.

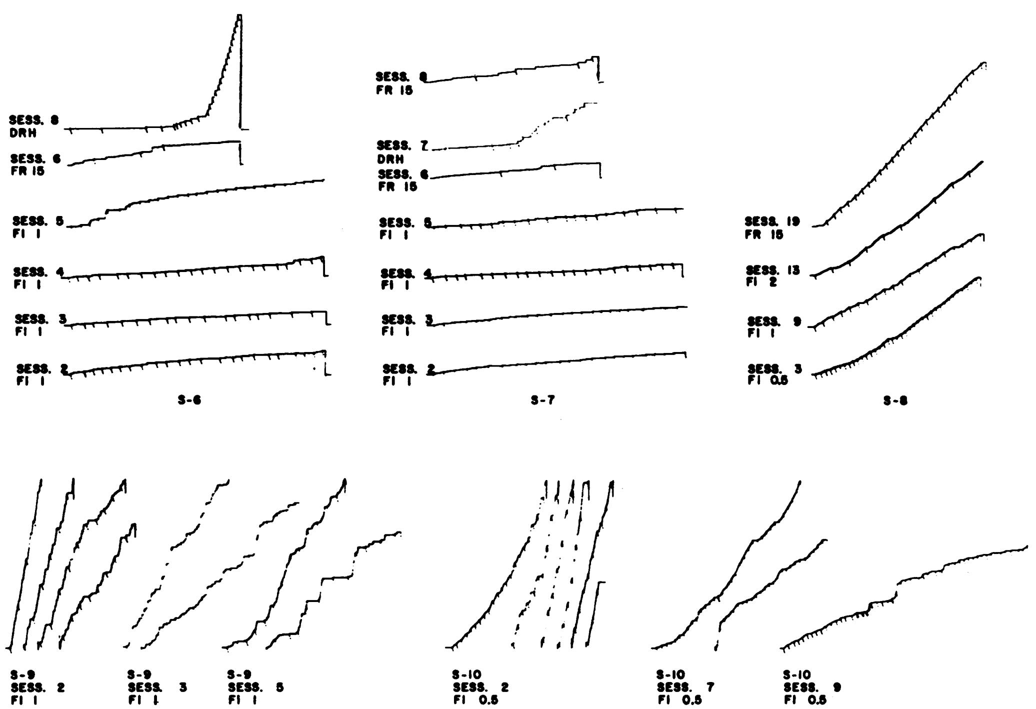

Figure 4. Cumulative records showing the variety of performances produced under FI.

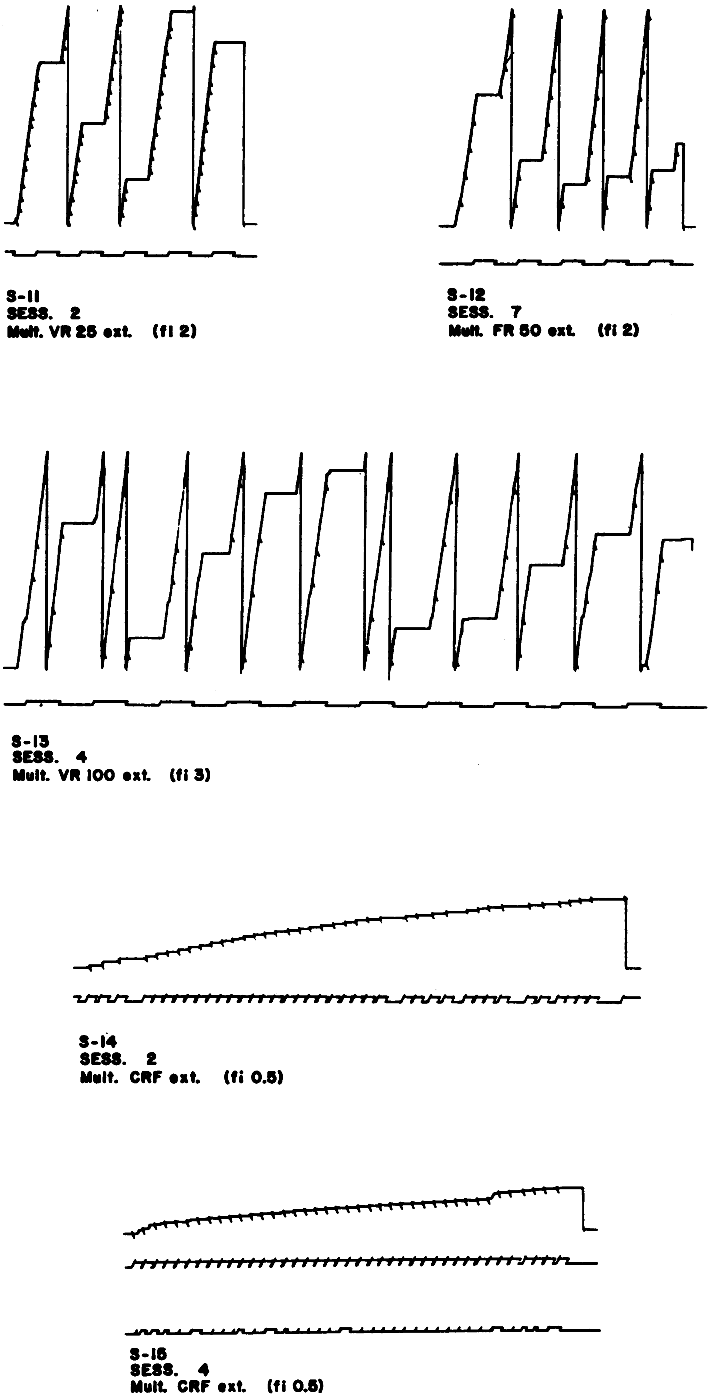

Figure 5. Criterion sessions under two multiple schedules, showing variations in schedule values and performance.

The last record for this *S* (Session 19) shows a ratio-produced increase in rate when shifted to FR 15, with a tendency for scallops to straighten out into ratio runs.

The records of S-9 illustrate the intermediate type of reaction to FI 1, with irregular rate and pause distribution. The FI control is weak, showing only in gradually decreasing rate and occasional scallops. Subject S-10 is an example of an *S* who started off very much like S-9, but who came under FI control much more positively, approaching an optimally low-rate solution.

Multiple Schedules

Mult VR ext. This schedule, which has proved especially useful in the study of discrimination learning, consists of two components, each signalled by a different stimulus (e.g., two colored jewel lights). One (e.g., red) serves as an S^{Δ}, and extinction is programmed in its presence; the other (e.g., blue) serves as the S^{D}, and a VR schedule is programmed in its presence. The two conditions alternate in regular fashion, either on a fixed time unit (e.g., every 2 minutes) or on variable time units (e.g., varying from 0.5 to 3.5 minutes). Discrimination performance is evaluated by an index of the number of correct responses (in the presence of S^{D}) to the number of incorrect responses (in the presence of S^{Δ}).

Figure 5 shows three variations in this schedule in *S*s whose performances met high criteria for discrimination. The event-pen line at the bottom of the records for *S*s 11, 12, and 13 indicates the color of the stimulus light present (the light serving as S^{D} varies). These records were selected to illustrate some of the range of schedules, session durations, and stimulus-alternation units that have been established and maintained. A technique for the rapid development of these schedules is described in detail in another paper (Bijou & Orlando, in press).

Mult CRF ext. This multiple schedule is a simple variation of interval schedules in that a cue is added; that is, reinforcements are programmed in the same way as in interval schedules, but a cue is presented at the end of the interval. This cue is withdrawn with every reinforcement and re-presented after the required interval has again elapsed. Discrimination performance is evaluated by the extent to which the *S* refrains from responding in the absence of the cue and the latency of response after cue onset. A DRL component requiring that the *S* pause in the absence of the cue may be added as a further variation which develops precise stimulus control.

Figure 5 shows records of this schedule (mult CRF ext with fixed 0.5 interval) in two *S*s who met high criteria of discrimination (*S*s 14 and 15). The event-pen line directly beneath the cumulative curves records cue duration; length of the line in the depressed position therefore represents latency.

The performance of S-14 is an example of a typical pattern in which there is almost no responding in the absence of the cue, but some rather long latencies occur. Subject S-15 responds occasionally during the interval (especially in the initial part of the session), but has consistently minimal latencies to cue onset. The lower event line in the record of S-15 is used to record duration of postreinforcement pauses; the pen is depressed by reinforcement and released by the first reponse. Length of the line in the depressed position therefore reflects durations of postreinforcement pauses.

CONCLUSIONS

The distinctiveness of behaviors generated by each type of schedule certainly seems no less than in infrahuman *S*s, although individual differences within schedule types may have a greater range. Response rate is clearly a function of the kind and values of schedules (at least within the range represented here); higher rates are associated with lower ratios, longer intervals, and variable rather than fixed schedules. Pause distributions and durations, along with scalloping and other patterning effects, seem less reliably generated by schedule control. (For example, FR postreinforcement pauses are not always stable within or among *S*s.) Effects are in the expected direction, however. For example, postreinforcement pauses are more likely in FR than in VR, and more likely with higher ratios compared with lower ones.

Stability of schedule control is fairly good in retarded children. Few intrasession or intersession "drifts" have been observed, particularly as the behavior approaches infrahuman "norms." Also, cumulative effects of warm-up, satiation, fatigue, boredom, etc., are minimal with candy as reinforcement.

The greater effectiveness of schedule control in retarded children than was reported for nonretarded children (Long, *et al.*, 1958) is probably attributable to differences in histories of deprivation and the type of reinforcer. Motivation is rarely a problem with the retarded, and such factors as number of reinforcers, duration of sessions, and intersession intervals have little effect on performance when candy is used.

Finally, the combination of schedule effects and stimulus control generated with multiple schedules holds great promise for the study of discrimination, generalization, and motivation of retarded children. More precise control of behavior is possible than with simple schedules, and performances which are quite sensitive to experimental conditions are easily obtained.

SUMMARY

Salient features of the behavior of developmentally retarded children as a function of simple and multiple schedules of reinforcement are illustrated. Effects of schedules are similar to those found with infrahuman *S*s as well as with nonretarded children. Two variations of multiple schedules are presented as particularly well-suited to the study of discrimination, generalization, and motivation in children because of the combination of stimulus and schedule control of performance.

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