INTERACTION BETWEEN THE COMPONENTS OF A CHAINED SCHEDULE

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The following study was carried out as a part of the current interest in our laboratory in the interrelationships of various components of complex programs of reinforcement. The schedule selected for study, a fixed-interval, fixed-ratio chain (chain FI FR), has been previously reported (Ferster & Skinner, 1957). This schedule is programmed so that the first response after the expiration of x minutes produces a stimulus change (a fixed-interval FI, schedule with a "secondary reinforcer"). A primary reinforcement, food, is then delivered immediately following the emittance of the "nth" response (a fixed-ratio, FR, schedule with food reinforcement), the stimulus being present from the first FR response until the actual presentation of the reinforcement. In Ferster and Skinner's experiments using pigeon subjects, the performance during the FR component of the schedule was typical of that generated by a simple FR schedule. A high rate of responding started abruptly with the onset of the stimulus and continued with almost no pausing until the reinforcement was delivered. The responding during the FI part of the schedule was typified by a pause after reinforcement, followed by steady or accelerating rates of responding until the stimulus change occurred. However, the chained performance showed less of the smooth acceleration in responding following the postreinforcement pause normally generated by an FI schedule. Responding during the FI portion of the chain frequently started suddenly, after a somewhat longer postreinforcement pause, and reached a high rate more quickly than with a simple FI schedule.

In the present experiment the relationships between the two components of the FI FR chain schedule were investigated. The scope of the study was restricted to the manipulation of the second component of the chain, i.e., the size of the FR. The FI was maintained at 4 minutes (FI 4), the dependent variable being the responding in the FI part of the performance.

SUBJECTS

Three male albino Wistar rats, approximately 1.5 years of age at the beginning of the study, were used. The animals were maintained, by restricted feeding of lab chow, at approximately 50% of their free-feeding weight (determined at 1 year of age). The rats had all experienced at least 200 hours on various values of the schedule, and had been used in an earlier study on the effects of different types of reinforcement on performance.

APPARATUS

A commercially available lever-pressing apparatus for rats (Foringer & Co.), with the necessary automatic programming equipment, was used for the study. The lever was a modified telegraph key, with an excursion of 0.125 inch, and required a pressure of 15 grams to close.

PROCEDURE

Approximately 0.25 cubic centimeter of sweetened condensed milk, delivered by a motor-driven dipper, was used as a reinforcement. Presented with the dipper as a secondary reinforcing stimulus was a 2000-cycle tone.

The 4-minute fixed interval (FI 4) of the schedule was not linked to a special stimulus. A click stimulus (10/second) was presented with the FR. This stimulus was presented when the FR contingency was in operation, i.e., when at least one lever press had been emitted following the expiration of the FI interval.

Daily experimental sessions were 2 hours in length. The rats were fed their supplementary ration immediately following the session, insuring constant deprivation time. The experiment was not run on weekends, but the feeding schedule was carefully maintained during those periods and other holidays.

Before the present experiment was undertaken, the rats had been well-stabilized on chain FI 4 FR 60 by at least 100 experimental hours. A planned series of changes of the FR component was made according to the following schedule, the value of the FI remaining at 4 minutes: FR 60, FR 5, FR 60, FR 120, FR 5, and FR 120. No change in the FR value was made until the performance on the preceding condition was considered stable, i.e., no apparent changes were noted for at least five sessions. This design, while not complete, does "recover" the performance for a particular value, allowing some evaluation of the independence of the behavior produced by a particular schedule value.

RESULTS AND DISCUSSION

The cumulative records of the performance produced by the three rats for each of the various conditions are shown in Fig. 1, 2, and 3. A 28-minute section of the cumulative

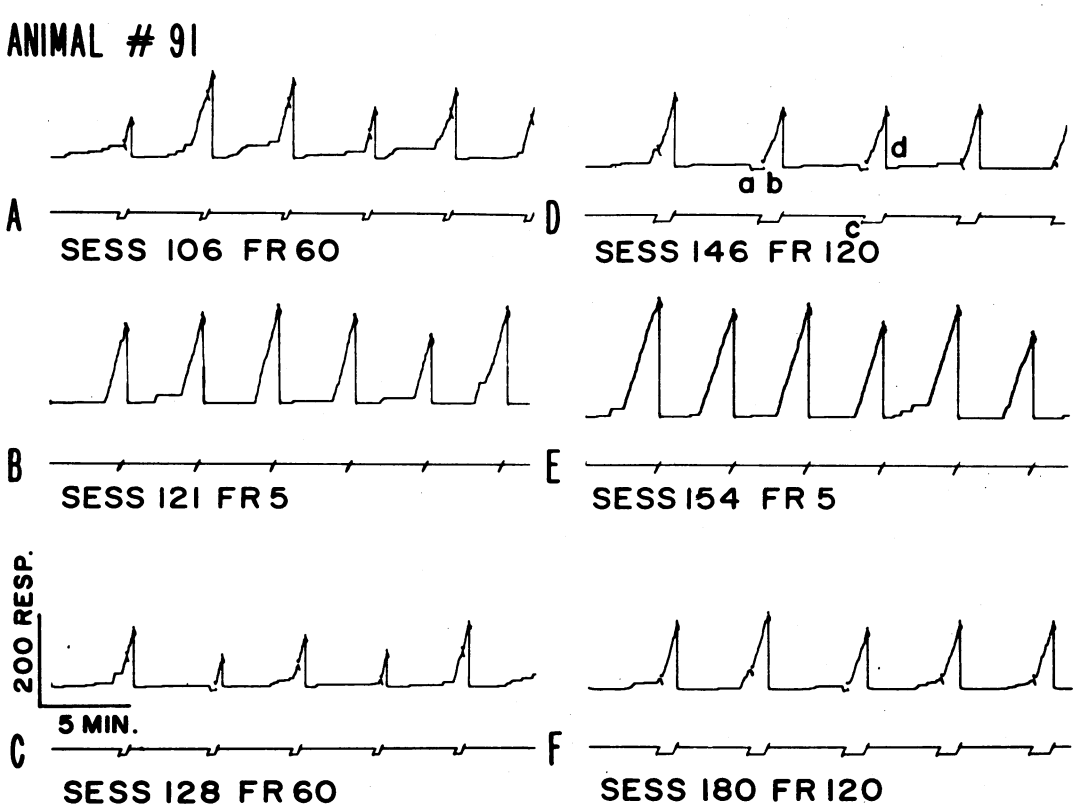

Figure 1. Cumulative records of performance on various values of chain FI FR. The value of the FR requirement was varied as indicated below the tracings. The interval duration was maintained at 4 minutes.

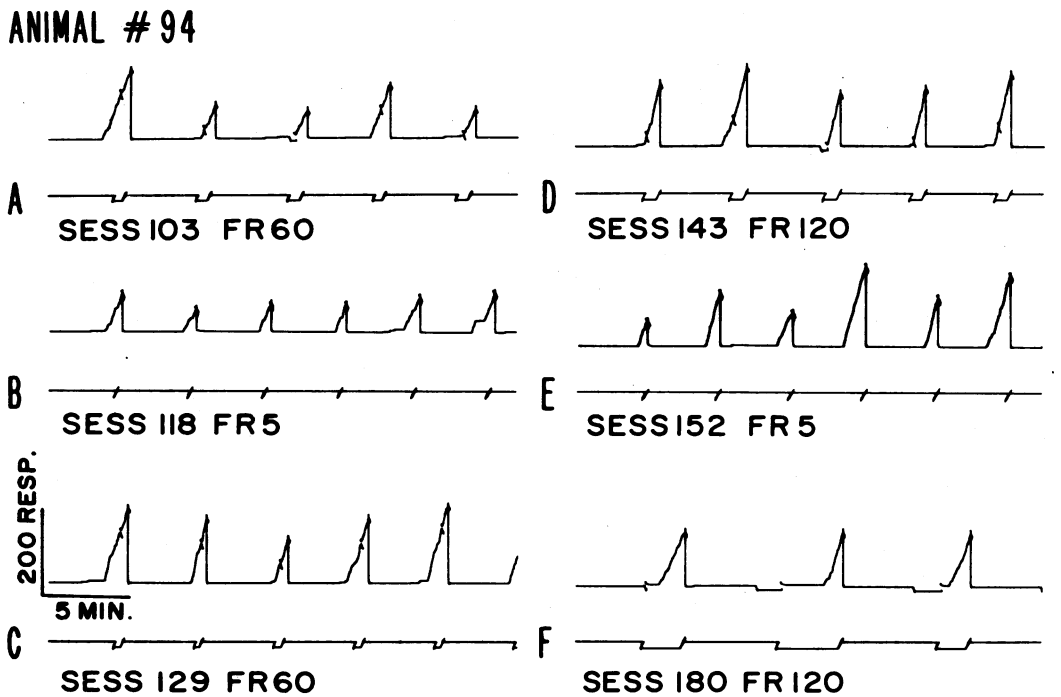

Figure 2. Cumulative records of performance on various values of chain FI FR. The value of the FR requirement was varied as indicated below the tracings. The interval duration was maintained at 4 minutes.

record produced during the 60th through the 80th minutes of the session was selected to show the typical performance. The records presented were usually collected in the last session before the change to a new schedule value. In a few cases, for technical reasons (apparatus failure, etc.), the immediately preceding record was selected. The records for the final FR value were taken from those collected several sessions before observable signs of sickness, both in the animals and reflected by the records, were noted. The actual session number is indicated with each tracing, along with the value of the FR component of the schedule.

Figure 1 represents the performance of Rat No. 91. The response pen off-set at the small letter *a* in tracing *D* indicates the expiration of the FI time requirement. The pen was returned at *b* with the first response, which also produced the FR stimulus which remained on until the reinforcement was presented. The duration of the FR component is marked by the off-set of the event pen *c*. Food reinforcements are recorded by the resetting of the response pen to the base line as at *d*, and by returning the event pen to the normal position. Figures 2 and 3 show the records of the other two animals in a similar fashion. The sections of performance shown by the cumulative records selected are not completely representative of the entire session. Normally, no matter what schedule was programmed, performance early in a session was erratic; and, usually, inappropriately high rates of responding were maintained. Within 30 minutes, however, stable performance was obtained and the remaining performance was usually quite regular, rarely showing any decrease in response rates as sometimes occurs with satiation.

Similarities in the over-all performance of the three rats on the various schedule values are apparent. Generally, the amount of responding occurring durring the FI component of

the schedule was dependent on the size of the FR requirement. The response rates are high for chain FI 4 FR 5, while FI responding is practically nil for chain FI 4 FR 120.

Changes between the terminal FI and the FR rates are not readily apparent under most of the conditions except FI 4 FR 120. Usually, with some exceptions, the FR requirement is fulfilled at the usual ratio rate, whether or not responding occurred in the FI, immediately following the emittance of the response terminating the interval and producing the click stimulus. This would indicate some degree of stimulus control. Rat No. 94 (Fig. 2) most clearly deviates from this pattern and shows something analogous to ratio strain on the high FR values (tracing *F*). Rat No. 98 (Fig. 3) shows the least ratio-like performance of the three, although responding to the onset of the clicker following an inactive FI interval is usually immediate and fairly continuous.

Figure 4 shows the temporal distribution of the responding occurring during the FI component of the schedules for the entire session for different FR values. The height of the shaded area represents the number of responses made during successive minutes of the interval performance divided by the actual number of intervals completed. The values are the averages of both final sessions on a particular FR value. These diagrams indicate both a marked control of the FI responding exerted by the FR requirement and excellent reproducibility of the effect among the three animals. The total amount of FI responding for an FR value of 120 was a very small fraction of that for the smallest FR requirement of 5 in each of the three animals. The temporal distribution of responses can also be seen to change

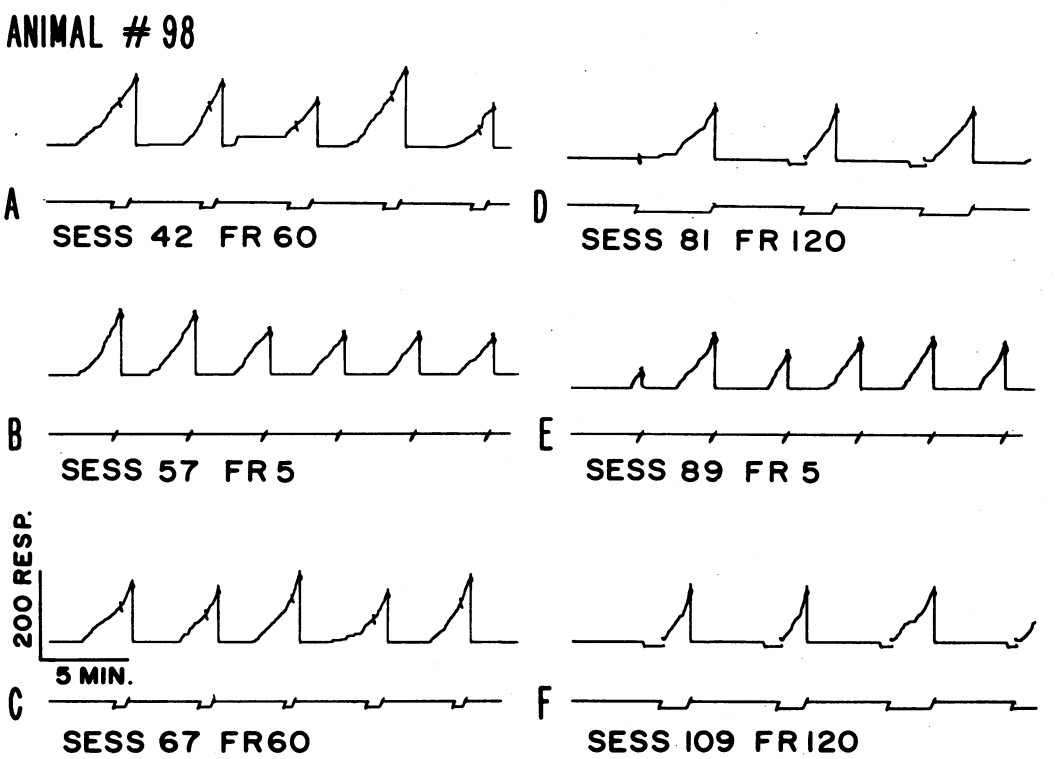

Figure 3. Cumulative records of performance on various values of chain FI FR. The value of the FR requirement was varied as indicated below the tracings. The interval duration was maintained at 4 minutes.

with the size of the FR, percentage-wise becoming much flatter with the higher FR requirements; but it does retain its major characteristic of increased responding with successive minutes.

It appeared possible that the amount of responding preceding a reinforcement, after long experience at the various schedule values, may have become constant, and that increasing the FR requirement only served to subtract such responses from those that would otherwise be emitted during the FI. Figure 5 presents the results of a closer analysis bearing on this possibility. Two curves are shown in the figure for each of the rats, each point representing the average number of *responses per reinforcement* emitted during the two final sessions for a particular schedule value. The upper dashed curve includes the total number of responses, the lower solid curve only those responses emitted during the FI component; the abscissa represents the numerical value of the FR requirement. The inverse relationship between the size of the FR requirement and FI responding apparent in Fig. 4 is reflected in the marked downward slope of the lower set of curves. The three rats produced similar functions, essentially linear and falling sharply with increasing FR values.

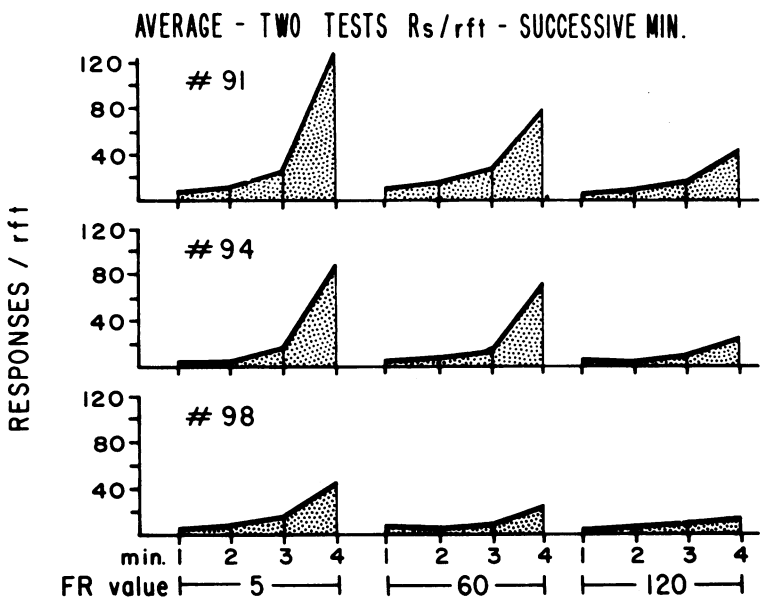

Figure 4. Temporal distribution of the responding occurring during the FI component of chain FI FR for three values of the FR requirement.

When the total number of responses per reinforcement is considered, at least within the range studied, the curves produced are fairly straight with a slight upward trend with increasing FR values. These curves indicate that slightly greater numbers of responses per reinforcement were emitted to the higher FR values. The upward trend of these curves suggests that a simple inverse relationship between the size of the FR requirement and FI responding does not completely describe these interactions. More total responses per reinforcement were emitted when there was a large FR requirement, indicating that something other than a simple learned unit of responding was controlling the recorded behavior.

It is interesting to speculate on what the shape of this function might be over a wider range of FR values. An FR requirement of 1 response is very close to a simple FI schedule. Considering the data collected in comparable animals on FI 4, such a chain schedule would probably have produced lower rates of FI responding than FI 4 FR 5, indicating that on our graph both curves would fall sharply at or shortly before FR 1. Judging from an extrapolation of the curves in Fig. 5, extreme values of the FR requirement would probably have resulted in little or no FI responding, bringing the lower curve to the zero level. Once the FI responding had become minimal, the upper curve could be expected to follow the incremental increase in FR values.

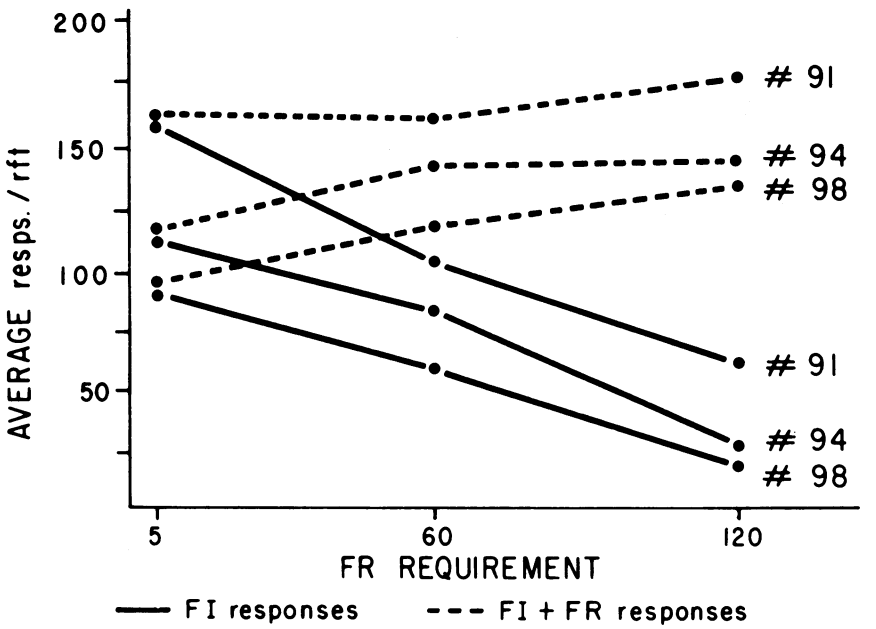

Figure 5. Average number of responses per reinforcement emitted on chain FI FR plotted against the value of the FR. The broken-line curve includes all responding. The solid lines indicate only FI responding.

The observed effects on the FI responding can also be discussed in terms of secondary reinforcement. Conceivably, the reinforcing properties of the stimulus produced on the FI schedule were manipulated by the values of the chained FR. The fact that higher FR values decreased the reinforcement value of the stimulus was discernible by the decreased FI responding. Such an analysis adds little to our understanding of the processes controlling chained behavior, and should probably be restricted to specific experiments designed to investigate such classes of reinforcement.

CONCLUSIONS AND SUMMARY

When the magnitude of the FR component of a chained FI FR is manipulated, performance in the FI is grossly affected. As the FR requirement is increased in value, responding in the FI essentially maintains its temporal distribution but is markedly reduced in an orderly manner with increasing FR values.

A slightly larger number of total responses per reinforcement was emitted when the larger FR requirements were programmed. The relationship between the total number of responses per reinforcement, FR size, and FI responding does not appear to be a simple one. A simple inverse relationship between FI responding and the size of the FR requirement does not completely describe the performance even for the values studied, and for extreme values obviously would be lacking.

REFERENCES

Ferster, C. B., and Skinner, B. F. *Schedules of reinforcement*. Appleton-Century-Crofts, New York, 1957.

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