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SOME EFFECTS OF FIXED-INTERVAL DURATION ON RESPONSE RATE IN A TWO-COMPONENT CHAIN SCHEDULE

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In Exp. I three pigeons were trained on a two-component chain schedule. Responding on a 1-min variable-interval schedule in the initial component led to a sequence of two fixed-interval schedules in the terminal component. The rate of reinforcement in the terminal component was kept constant while the values of the two fixed intervals were varied. Three combinations of fixed-interval schedules were studied, FI 0.25, FI 1.75 (minutes) or FI 1.00, FI 1.00, or FI 1.75, FI 0.25. The rate for each subject declined in the initial component as the value of the first fixed interval was increased. Experiment II was conducted to assess the role of the second fixed-interval schedule in the terminal component in determining the rate of responding in the initial component. For each chain schedule the rate of responding in the initial component was determined both with and without the second of the sequence of fixed intervals. In all three cases the rate of responding in the initial component decreased when the second fixed interval was removed. Increasing the first fixed interval in Exp. I had a greater effect on variable-interval performance than did the removal of the second fixed interval in Exp. II.

In a two-component chain schedule a subject responds in the presence of two successive exteroceptive stimuli. The only programmed consequence of responding in the initial component is the appearance of the stimulus correlated with the terminal component. In the terminal component the subject receives one or more primary reinforcements. In either component a variety of schedules of reinforcement may be used (Ferster and Skinner, 1957; Kelleher and Gollub, 1962).

The maintenance of responding in the initial component of the chain schedule is attributed to the appearance of the stimulus associated with the second component, in which primary reinforcement is received (Kelleher and Gollub, 1962). In any given chain schedule a number of variables presumably determine the rate of responding in the initial component. One variable which has received considerable attention is the rate of reinforcement in the second component (Herrnstein, 1964*a*; Kelleher and Gollub, 1962; Kelleher, 1966). In their review of positive conditioned reinforcement, Kelleher and Gollub state: "The evidence indicates that the conditioned reinforcing effectiveness of a stimulus is directly related to the frequency of primary reinforcement occurring in its presence, but is independent of the response rate or response pattern occurring in its presence," (Kelleher and Gollub, 1962, p. 543).

McDiarmid and Rilling (1965) have pointed out that the rate of reinforcement and the delay to the first reinforcement usually covary. In their experiment, pigeons preferred a stimulus correlated with a short delay to the first reinforcement, even though choosing the alternative stimulus allowed a higher rate of reinforcement.

The present study was designed to study behavior in a two-component chain schedule in which the delay to the first primary reinforcement was systematically varied while providing a constant rate of primary reinforcement. A further consideration was the role of the second reinforcement in the terminal component of the chain. Perhaps the rate of responding in the initial component is governed solely by the immediate consequences of entering the terminal component. It is of interest to discover whether or not the more remote portions of the terminal component influence behavior in the initial component.

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EXPERIMENT I

Subjects

Three pigeons, two of which were Silver Kings, designated SK-30 and SK-91, and the third a white pigeon, designated "Friendly", whose exact breed was unknown, were used. The two Silver Kings were naive but Friendly had frequently been used to check out new experimental programs. The age and sex of all birds were unknown.

Apparatus

A two-key pigeon chamber (Kendall, 1965) was housed in a larger sound attenuating chamber. The interior was illuminated by a 15-w light bulb located in a separate compartment above the roof of the pigeons' compartment. The onset and offset of this light signaled the beginning and end of the session. The right-hand key was covered with tape. Programming was accomplished with standard electromechanical components and data were collected on a cumulative recorder, counters, and running time meters.

Procedure

A variable-interval schedule with a mean of 1 min (VI 1-min) was used for the initial component of the chain schedule. Thus, the first response after varying periods of time produced the stimulus associated with the terminal component. This schedule was used throughout both experiments. No light was displayed on the key during VI 1-min. The terminal component was composed of two successive fixed-interval (FI) schedules which were programmed in the presence of a yellow key-light. In FI, the first response following the passage of at least a fixed period of time produces reinforcement.

In the presence of the yellow light two 5-sec grain reinforcers were delivered, one for each of the two FIs. The duration of the terminal component was 2 min throughout the first experiment. Thus, setting the first FI fixed the value of the second FI. After reinforcement for the second FI, the subjects were returned immediately to the first component. Since no exteroceptive stimuli differentiated the second FI from the first, the second component may be described as a mixed FIx FIx (mix FIx FIx) and the entire schedule is referred to as a chain (VI 1) (mix FIx FIx).

The values of the FIs programmed in the second component were FI 0.25, FI 1.75, or FI 1, FI 1, or FI 1.75, FI 0.25, all values in minutes. Since two reinforcements were delivered in 2 min under each of the mix FIx FIx conditions, the rate of reinforcement in the second component was constant throughout the experiment while three different FI combinations were studied.

Birds SK-91 and SK-30 were trained by successive approximations to peck the key and then trained on one of the mix FIx FIx schedules in the presence of the yellow light for about a week. Each bird was then given one session of the chain schedule in which each response in the first component produced the yellow light associated with the second component. The birds were then placed on the complete chain schedule. One subject, Friendly, had already been trained to peck the key when the experiment began. When the variable-interval rate was stable, a subject was transferred to a new chain schedule without further training.

Each bird responded at each value of the mix FIx FIx for at least 30 sessions. A session consisted of 40 grain reinforcements. Variable-interval response rates for the final six sessions were computed and evaluated for stability. The only criterion for stability was that the rate show no systematic trend. The actual amount of variability tolerated depended on the schedule under consideration, since variability was greater when the first fixed interval was longer. If the rates did not appear stable after 30 sessions the subject was continued on that particular schedule until stability was satisfactory. In some cases up to 50 sessions were necessary.

The sequence of mix FIx FIx schedules for each bird was as follows: Friendly and SK-30: FI 0.25 FI 1.75, FI 1 FI 1, FI 1.75 FI 0.25; SK-91: FI 1.75 FI 0.25, FI 0.25 FI 1.75, FI 1 FI 1.

Results

The average VI rates under each condition for each subject can be seen in Fig. 1. The VI rate for each subject decreased systematically as the first FI was increased. An increase in the minimum time from the onset of the terminal component to the first primary reinforcement led to a decrease in response rate in the initial component, even though the rate of reinforce-

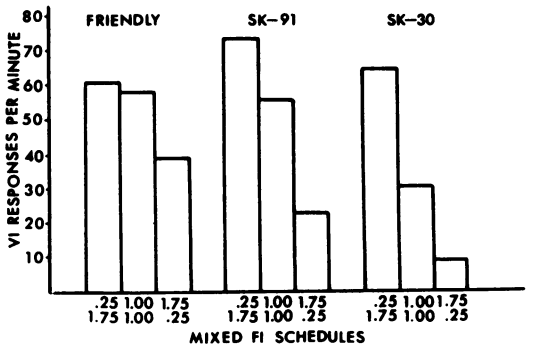

Fig. 1. Average VI response rates in the initial component for each subject under each of the three mix FIx FIx conditions.

ment in the terminal component remained constant.

Cumulative records for each subject under each condition are shown in Fig. 2. The transition from the initial to the terminal component is marked by an arrow. This transition is usually visible in the FI 0.25, FI 1.75 records. There was a change from a fairly high VI rate to a very high FI rate. The first reinforcement was frequently followed by a pause and positive acceleration of responding in the second FI. The reinforcement for the second FI is marked by a dot.

The cumulative records for the FI 1.00, FI 1.00 show positive acceleration of responding in both FIs for SK-91 and Friendly. SK-30 sometimes showed positive acceleration during the second FI but not during the first.

The transition between the initial and terminal components is more difficult to detect in the FI 1.75, FI 0.25 records because of the fairly low VI rate which was followed by a fairly low rate in the initial part of the first FI. The first primary reinforcement was followed by a high rate during FI 0.25.

Generally, these records would support the conclusion that each component was under appropriate control. Further, the first primary reinforcement in the terminal component usually was followed by behavior appropriate to the second FI.

The average rates of responding in FI are shown in Fig. 3. In all cases where FI 0.25 and FI 1.75 occurred in the terminal component the FI 0.25 rate was higher than the FI 1.75 rate. This further substantiates the conclusion that each FI came under appropriate control. For two subjects, SK-91 and SK-30, the response rate was lower in the second FI where the FI schedules were FI 1.00, FI 1.00. This is similar to a finding of Findley's using a series of fixed-ratio schedules in the terminal component of a chain (Findley, 1962 p. 131).

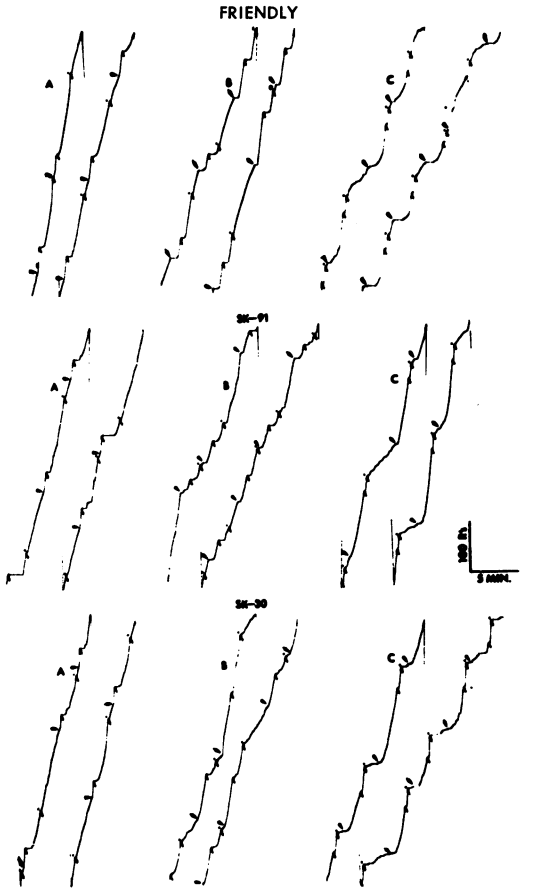

Fig. 2. Cumulative records for each subject under each of the mixed FI FI schedules. Records labeled "A" are for mix FI 0.25 FI 1.75. Those marked "B" are for mix FI 1.00 FI 1.00 and those marked "D" are for mix FI 1.75 FI 0.25. An arrow marks the point of transition from VI to the first FI. A dot is placed above the reinforcement for the second FI.

Two subjects were trained on one tandem schedule each. The sole difference between the tandem and chain schedules is that only one exteroceptive stimulus is present in the tandem. In this case the response key remained dark throughout each session. The dark key was the VI stimulus for the initial component in the corresponding chain schedule. SK-91 was trained on tand (VI 1) (mix FI 1.75 FI 0.25), Friendly was tested under tand (VI 1) (mix FI 0.25 FI 1.75). Figure 4 compares the

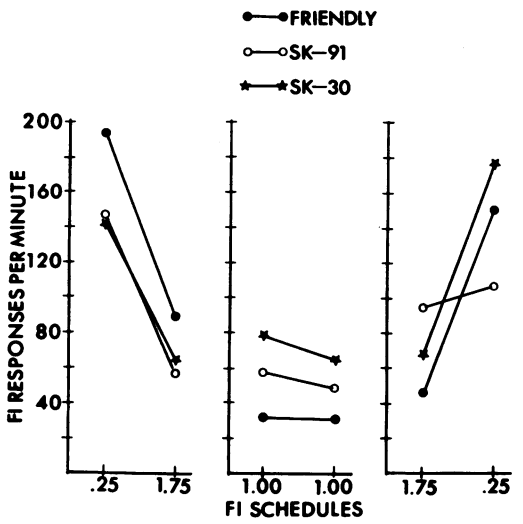

Fig. 3. Average FI response rates for each subject under each of the three mixed FI FI schedules. The first panel shows the response rates for mix FI 0.25 FI 1.75. The second panel shows the response rates for mix FI 1.00 FI 1.00 and the third shows response rates for mix FI 1.75 FI 0.25.

tandem and chain VI rates for these two subjects. In both cases the tandem rate was higher than the corresponding chain schedule rate. The difference was substantial for SK-91 and small for Friendly. This finding, especially in the case of SK-91, is similar to some results obtained in extended chain schedules which use more than two components (Kelleher and Gollub, 1962; Kelleher, 1966).

EXPERIMENT II

In Exp. I the rate of responding in the initial component depended on the FI values in the terminal component of a chain schedule. It is not known whether the second FI of the terminal component contributed anything to the conditioned reinforcing value of the stimulus associated with the terminal component. If only the first FI determined the rate of responding in VI, then Exp. I becomes a systematic replication of data reported by Ferster and Skinner (1957).

In Exp. II the removal of the second FI of the terminal component was studied. This alters the rate of primary reinforcement in the terminal component in two of the schedules. It also alters the number of reinforcements in the terminal component in all of the chain schedules. If the second FI is removed from the FI 0.25 FI 1.75 condition, the rate of reinforcement in the terminal component is increased. Similarly, if the second FI is removed from the FI 1.75 condition, the rate of reinforcement is decreased in the terminal component. The rate of reinforcement is not altered if the second FI is removed in the FI 1.00, FI 1.00 condition.

If behavior in the initial link is sensitive to the rate of reinforcement in the terminal component, the direction of the response rate change in the initial component should be predictable when the second FI is removed. On the other hand, if only the first FI controls behavior in the initial component, no change in response rate in that component should be observed when the second FI is removed. If behavior in the initial component is sensitive to the total number of primary reinforcements in the terminal component, a decrease in response rate should be observed in all three chain schedules.

Subjects

Two subjects from Exp. I were used (SK-30 and SK-91), supplemented by two naive Silver Kings (SK-46 and SK-99).

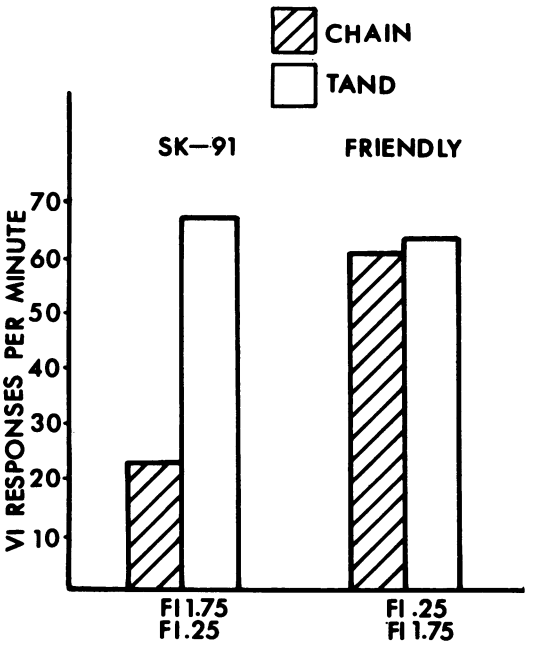

Fig. 4. Average VI response rates in the initial component under chain tandem schedule conditions for SK-91 and Friendly. SK-91 performed on chain and tandem VI 1 FI 1.75 FI 0.25, Friendly on chain and tandem VI 1 FI 0.25 FI 1.75.

Procedure

After performance stabilized on one of the three chain schedules described in Exp. I, a subject was placed on a chain schedule consisting of the VI 1-min component and the first of the pair of FIs. After a single reinforcement on FI, the bird was returned immediately to VI. When stability had been achieved on this schedule (chain VI 1 FIx) the subject was returned to the original chain schedule with both FIs.

The two new birds were trained in the same way as the subjects in Exp. I. Stability was evaluated in the same way except that each subject was not required to take 30 sessions under each condition. The rate changes in this experiment occurred relatively rapidly.

Results

The results of this experiment are shown in Fig. 5. Variable-interval rates are shown for each subject under each condition. With one exception, the removal of the second FI schedule lowered the rate in VI. The exception was SK-30 in the shift from FI 1.75 FI 0.25 to FI 1.75. This bird behaved similarly to the other two under the shift from FI 0.25 FI 1.75 to FI 0.25. No reason is evident for this reversal of the general effect.

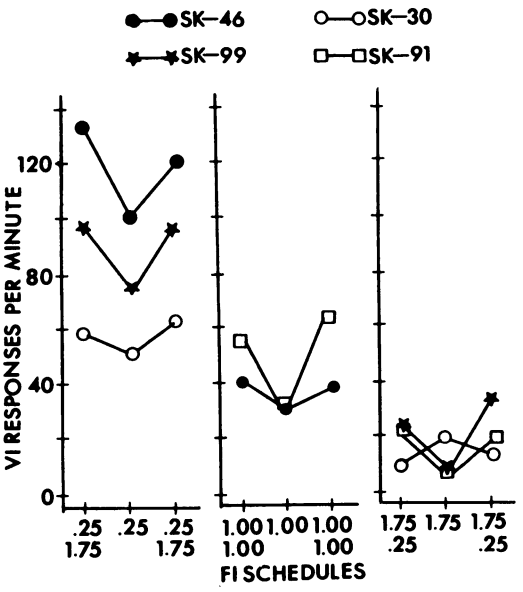

Fig. 5. Average VI rates for each subject under each condition. The first point in each panel is the "baseline" condition where both FIs were presented. The second point is the VI response rate with the second FI eliminated. The third point is the return to baseline.

The results in Fig. 5 replicate those presented in Fig. 1 of Exp. I. Figure 5 also shows a decrease in VI response rate as the duration of the first FI was increased.

DISCUSSION

The data from Exp. I relate to experiments performed by Herrnstein (1964) and McDiarmid and Rilling (1965). Herrnstein, using concurrent chain schedules, showed that the rate of responding was higher on a key that led to a VI schedule than on one that led to a FI schedule in a condition where the mean of the VI schedule was the same as the duration of the fixed interval. He concluded that the short times to reinforcement occurring in the VI schedule were responsible for this preference.

McDiarmid and Rilling (1965) directly opposed rate of reinforcement and time to the first reinforcement in a choice experiment. They showed that pigeons preferred a schedule with a short time to the first reinforcement even when the alternative response led to a condition with a higher rate of reinforcement.

The results of Exp. I demonstrate a similar effect in a single-key chain schedule. The response rate in the initial component of a two-component chain schedule is lowered the longer the time from the beginning of the terminal component to the first primary reinforcement, even though the rate of reinforcement remains constant.

This kind of correlation between results of single-key experiments and concurrent schedules has been demonstrated by Herrnstein (1961) and Catania (1963). Herrnstein (1961) showed that the relative rate of responding on a key was linearly related to the relative rate of reinforcement obtained by responding on that key. Previous single-key experiments had demonstrated an increase in response rate as the frequency of reinforcement increased (Clark, 1958; Wilson, 1954). Catania showed that the relative rate of responding on a key increased as the reinforcement magnitude was increased for responses on that key. In addition, the concurrent schedule appeared to be more sensitive in that fairly large and enduring changes occurred in Catania's experiment,

whereas they had not in single-key experiments (Jenkins and Clayton, 1949; Keesy and Kling, 1961).

Wyckoff (1959) speculated that the curve relating the effectiveness of a conditioned reinforcer to cue strength is positively accelerated over part of its range. Cue strength should be related to such variables as the delay of reinforcement, reinforcement schedule, *etc.* Applied to Exp. I, his hypothesis would predict a non-linear relationship between VI rate and the various pairs of FI schedules. Generally, the data presented in Fig. 1 would not support this hypothesis. The functions for subjects SK-91 and SK-30 appear to be linear, while that for Friendly appears to be non-linear. The required non-linearity might be produced if a wider range of FI values were used.

Kelleher and Gollub (1962) have discussed the use of tandem schedules as control procedures for chain schedules. If conditioned reinforcement is operating in the chain schedules, rates of responding in the initial component of a chain schedule should be higher than in the comparable tandem. In the chain-tandem comparisons in this study, the response rate was higher in the initial component of the tandem than in the chain schedule. An analysis of tandem schedules in terms of the interresponse times preceeding reinforcement (Morse, 1966) would lead to the prediction that, in some instances, rates of responding in the initial component of a tandem schedule will be higher than in the corresponding chain and in some instances lower. This should occur because no discrimination between the components is possible in the tandem schedule and behavior appropriate to the terminal component may appear earlier than in the chain schedule. Such an analysis should lead to a more careful evaluation of the tandem schedule as a control procedure for the chain schedule.

While the results of Exp. II were somewhat unexpected, they do demonstrate that behavior in the initial VI component of the chain schedule was sensitive to the presence of both FIs in the terminal component (Kelleher and Gollub, 1962). Nevertheless, it would be expected that changes in response rate in the initial component would occur when substantial changes of reinforcement rate do occur in the terminal component. In the schedule where reinforcement rate decreased when the second fixed interval was removed (FI 1.75, FI 0.25), the changes in response rate in the initial component were appropriate to the change in reinforcement rate. In the other two schedules, however, there was either no change in reinforcement rate in the terminal component (FI 1.00, FI 1.00) or the reinforcement rate increased (FI 0.25, FI 1.75). In both cases, the response rate in the initial component decreased when the second fixed interval was removed.

The response rate changes in the initial component could be attributed to a decrease in the number (as opposed to rate) of reinforcements in the terminal component. This variable has not been suggested as a major parameter of chained schedules and there appear to be no previous experiments demonstrating such an effect. It should be noted that as the number of reinforcements decreases in the terminal component, the proportion of time spent in the terminal component also decreases. There is evidence that increasing the amount of time spent in the initial component of a chain schedule will affect response rate in the terminal component (Findley, 1962, p. 129 ff). There is no evidence however, of an effect in the opposite direction. In addition, it would be impossible to alter the proportion of session spent in the terminal component without also changing either the rate or number of reinforcements.

Of the two variables studied in the two present experiments, the effect of increasing the duration of the first FI was more powerful than removing the second FI. This may best be seen in Fig. 5. The second experiment sought to discover if events in the chain remote from the initial component could influence behavior in the initial component. Experiment II demonstrated this to be the case, but the influence on behavior in the initial component of the chain was not as great as when the duration of the first FI was increased.

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