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Two-Component Chained Schedules of Reinforcement and Fixed Interreinforcement Time

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TWO-COMPONENT CHAINED SCHEDULES OF REINFORCEMENT AND FIXED INTERREINFORCEMENT TIME

by

Philip D. Bruce

A Thesis
Submitted to the
Faculty of the Graduate College
in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
Kalamazoo, Michigan
August, 1972

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ACKNOWLEGMENTS

I wish to thank Dr. David O. Lyon for his guidance and emotional support throughout this entire investigation. Drs. Arthur Snapper and Howard Farris are also extended a token of gratitude for their helpful comments. A special note of thanks is extended to my wife, Karen, for her incessant inspiration throughout the entire year at Western Michigan University. Also, a sincere "thank you" goes to Patty Cronk for her efforts in the typing of this manuscript.

Philip D. Bruce
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</tr>
</tbody>
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INTRODUCTION

Chained schedules of reinforcement have been utilized primarily as techniques in the investigation of conditioned reinforcement. A sequence of schedules, each signalled by a different exteroceptive stimulus, eventually terminates in primary reinforcement. Each subsequent stimulus in the sequence is assumed to be a conditioned reinforcer for responding in the presence of the preceding stimulus.

One of the main findings with two-component chained schedules has been that the conditioned reinforcing strength of the terminal component stimulus is a direct function of the frequency of primary reinforcement occurring in its presence (Kelleher and Gollub, 1962). Thus, higher rates of responding are maintained in the initial component if the reinforcement frequency in the terminal component is high. However, overall interreinforcement time has not remained constant in many of these studies. Consequently, the main purpose of the present investigation is to study two-component chained schedules in which the interreinforcement time is held constant. In addition, an attempt will be made to determine if changes in the rate of responding during the initial component reflect changes in the overall interreinforcement time, rather than the strength of the terminal component stimulus.

Autor (1960) studied the performance of pigeons on a two-component variable-interval (VI) chain, using a concurrent chaining procedure. The initial component on both keys was a VI 1-minute
schedule. The terminal component on one key (key A) was held constant at VI 15-seconds, while the terminal component on the other key (key B) was systematically decreased from VI 1-minute to VI 3.75-seconds. The response rates in the initial component of the chain on key B increased in a linear fashion as the frequency of primary reinforcement was increased in the terminal component, by reducing the VI 1-minute schedule to a VI 3.75-second schedule. These data were interpreted as demonstrating that the conditioned reinforcing strength of the terminal component stimulus on key B increased as the frequency of primary reinforcement also increased. An alternative hypothesis to account for the results of the experiment might be that an overall reduction in the mean interreinforcement time from 2-minutes (chain VI 1-minute VI 1-minute) to 1-minute and 3.75-seconds (chain VI 1-minute VI 3.75-seconds) produced the rate increases, and not the presumed strength of the conditioned reinforcer. Other chaining studies are also subject to this possible confounding (e.g., Findley, 1954, and 1962; Ferster and Skinner, 1957; and Herrnstein, 1964), since they involved either increasing or decreasing interreinforcement time.

Perhaps one reason for the possible oversight of this variable is the failure to use tandem control procedures. Considering the sixteen studies investigating the effects of the frequency of primary reinforcement or conditioned reinforcement, cited by Kelleher and Gollub (1962, p. 550), none of these studies employed this control procedure across all chaining conditions. The only difference between the tandem and chained schedule is that the same exteroceptive
stimulus appears in all components of the tandem, while a different stimulus appears in all components of the chained schedule. There is apparently only one study which has employed this control procedure while investigating the frequency of primary reinforcement. Thomas (1967) trained subjects on a three-component tandem schedule in which a fixed-interval (FI) schedule of 1-minute appeared in each component. Subsequently, the subjects were exposed to a three-component chain with identical schedule parameters. The frequency of primary reinforcement was then increased in the terminal link by reducing the FI 1-minute schedule to FI 45-second, FI 30-second, and FI 15-second schedules. Rate increases appeared in the initial component of the chain; however, a replication of this procedure with the tandem schedule also produced rate increases in the initial component. Hence, Thomas concluded that conditioned reinforcement could not account for the results; rather, a change in the overall contingencies of reinforcement of the chain produced the rate increases.

On the basis of the Thomas investigation, it would appear that tandem schedules are important control procedures, and as a result, were incorporated into the present study as controls for all chain conditions. However, the criteria for concluding that a stimulus may be a conditioned reinforcer are not clear, even when the tandem has been used as a control procedure. Kelleher and Gollub (1962) have referred to the pattern of responding within components, as well as the overall rate of responding as joint criteria for conditioned reinforcement. If the pattern of
responding within components is characteristic of the schedule in effect, and the rates of responding are elevated above those of the tandem control procedures, this is assumed to be evidence for conditioned reinforcement. Yet, it is not certain whether both criteria must be satisfied, or only one. For example, Gollub (1958) has reported rate increases in the initial component of a two-component chain, and positively accelerated responding sometimes occurred within components. Kelleher and Fry (1962), however, in a three-component tandem and chain study, reported decreased response rates in the first and second components of the chain, and positively accelerated responding in the second component. They interpreted their results as evidence that the appearance of the third-component stimulus of the chain was a conditioned reinforcer, despite the rate decrease in the second component.

This difficulty complicates the conclusions of any experiment, and one is forced to conclude that changes in the rate and pattern of responding on a chain, when compared to a tandem control, are only the result of the presence of different exteroceptive stimuli in each component. Other experiments or control procedures must be utilized to determine the functions of stimuli, and differing interpretations remain plausible alternatives if only tandems and chains are compared in a given experiment.

Wike (1966) has suggested the addition of an independent control procedure to evaluate the rate of responding in the initial component. Responding in the initial component could produce a
stimulus other than the one correlated with the terminal component. This control procedure could be compared with the original chaining condition, and if a rate increase was not observed in the initial component of the control, it would rule out the possibility that any stimulus might produce a rate increase. However, it might be added that depending upon the number of sessions in which subjects were exposed to this procedure, it would not necessarily eliminate a conditioned reinforcement interpretation. The stimulus still would directly precede primary reinforcement, hence, is capable of acquiring conditioned reinforcing properties over time.

In the present investigation, a non-paired brief stimulus procedure is proposed as an independent control. A non-paired brief stimulus procedure is one in which the stimulus remains the same in both components, but a different stimulus that is never directly paired with primary reinforcement is programmed, response-contingent, upon the completion of a component (Kelleher, 1966). The duration of the brief stimulus is usually 0.5 to 1.0-seconds. The use of this procedure may possibly aid in determining whether stimulus change, per se, produces a change in the rate or pattern of responding in chained schedules.
METHOD

Subjects

Three female White Carneaux pigeons, maintained at approximately 70% of their free-feeding weights, served as subjects. Two subjects (A-5 and A-15) were experimentally naive at the beginning of the experiment, and one subject (A-3) had a prior history of three-component tandem and chained schedules of reinforcement. Grit and fresh water were available at all times in the home cages.

Apparatus

A 12 x 12 x 10 inch response panel was enclosed in a sound attenuated chamber with forced air ventilation. A Gerbrands response key was located 8 inches above the floor, and required an operating force of 15 grams. The response key was illuminated by a red or blue light, and produced an auditory click for each effective key peck. Mixed grain reinforcement was made available through a 2 x 2 inch opening which was 4 inches below the response key. A speaker provided white masking noise, and was generated by a Grason-Stadler Model 901B noise generator. The experiment was programmed by appropriate electro-mechanical equipment, and the data were recorded from counters, running time meters, and a Gerbrands cumulative recorder. No houselight was used throughout the experiment.
General Procedure

Experimental sessions were conducted seven days per week, and lasted until the subjects had received 30 reinforcements, each consisting of a 4-second access to mixed grain. Subjects A-5 and A-15 were initially trained to peck the response key by appropriate shaping techniques, and were subsequently exposed to continuous reinforcement for three sessions. They were then trained on a fixed-interval (FI) 90-second schedule in which the first response occurring after 90-seconds produced reinforcement. Subject A-3 did not require preliminary training because of past experimental training.

Phase One

Subjects A-5 and A-15 were exposed to a tandem FI 60-second FI 90-second schedule. The first response after 60-seconds placed the animal into the FI 90-second component, and the first response following the completion of the FI 90-second component was reinforced with grain. The key light was red in both components of the tandem schedule. Following this condition, the animals were placed on chain FI 60-seconds FI 90-seconds, in which a blue key light appeared in the 60-second component, and a red light appeared in the 90-second component. After exposure to this set of schedules, the sequence of schedules was reversed, and the order of conditions was tandem FI 90-seconds FI 60-seconds and chain FI
90-seconds FI 60-seconds. The key light was red in both components of the tandem. A blue light appeared in the initial component of the chain, followed by a red light in the terminal component. The interreinforcement time remained constant across all of these conditions at 150-seconds.

Phase Two

Subject A-3 served as an independent control subject, and was exposed to a set of non-paired brief stimulus schedules (BSn). Only the interreinforcement time of 150-seconds was investigated, and the schedules were BSn FI 60-seconds FI 90-seconds and BSn FI 90-seconds FI 60-seconds. The color of the key light was blue in both components, and the first response occurring at the end of the initial component changed the color of the key light to red for 0.5-seconds. Subsequently, the key light changed back to blue, and primary reinforcement occurred upon the emission of the first response at the end of the second component.

Phase Three

Subject A-15 was exposed to a tandem and chained schedule with an interreinforcement time of 120-seconds. The schedule values were FI 90-seconds FI 30-seconds. The key light was red in both components of the tandem. A blue key light signalled the FI 90-second schedule in the chain, and a red light was used to signal the FI 30-second component.
Determinations of stability for the experiment were as follows:
Subjects A-5 and A-15 were exposed to the first condition of the experiment for a minimum of 20 sessions. A stability criterion of no consistent trend in response rates over the last five sessions was used. If subjects were not judged to be stable, sessions were continued until the rates were stable over five sessions. For all other conditions there was a minimum of 15 sessions exposure, and conditions were changed when rates were stable for five sessions. Subject A-3 was run for 15 sessions under both brief stimulus schedules because of prior experience with an interreinforcement time of 150-seconds.
RESULTS

The mean response rates per minute and the number of experimental sessions conducted for each bird in the first phase are presented in Table 1. The mean response rates are those of the last 5 sessions for each condition. Rates are presented separately for the initial and terminal links of each schedule, and the overall rates of responding for both components.

When the interreinforcement interval remained constant at 150-seconds, the rates of responding in the initial links of the chained schedules generally show a decrease, when compared to the tandem controls.

**FI 60-seconds FI 90-seconds:** Subject A-5 displayed a slight decrease in responding in the initial link of the chain, when compared to the large decrease of about 13 responses per minute for subject A-15. However, both subjects slightly increased response rates in the terminal links in approximately the same manner (about 2 responses per minute). The difference in the overall rates of the tandem and chain for each subject also reflects the same decreasing trend in response rates.

Despite the greater decrease in the initial link for subject A-15, similar initial and terminal link rates were produced by the chaining condition for both subjects. The overall rates are also similar.
Table 1

MEAN RESPONSE RATES PER MINUTE AND THE NUMBER OF SESSIONS CONDUCTED FOR PHASE ONE

<table>
<thead>
<tr>
<th>Pigeon</th>
<th>Condition</th>
<th>Sessions</th>
<th>Initial Link</th>
<th>Terminal Link</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-5</td>
<td>tand 60-90</td>
<td>25</td>
<td>7.37</td>
<td>49.34</td>
<td>29.76</td>
</tr>
<tr>
<td></td>
<td>chain 60-90</td>
<td>41</td>
<td>6.09</td>
<td>51.40</td>
<td>29.03</td>
</tr>
<tr>
<td></td>
<td>tand 90-60</td>
<td>25</td>
<td>21.35</td>
<td>88.37</td>
<td>47.40</td>
</tr>
<tr>
<td></td>
<td>chain 90-60</td>
<td>19</td>
<td>11.77</td>
<td>63.51</td>
<td>29.28</td>
</tr>
<tr>
<td>A-15</td>
<td>tand 60-90</td>
<td>27</td>
<td>19.52</td>
<td>43.48</td>
<td>34.09</td>
</tr>
<tr>
<td></td>
<td>chain 60-90</td>
<td>16</td>
<td>6.67</td>
<td>46.03</td>
<td>27.40</td>
</tr>
<tr>
<td></td>
<td>tand 90-60</td>
<td>17</td>
<td>20.00</td>
<td>60.31</td>
<td>35.40</td>
</tr>
<tr>
<td></td>
<td>chain 90-60</td>
<td>15</td>
<td>12.61</td>
<td>49.40</td>
<td>26.92</td>
</tr>
</tbody>
</table>
**FI 90-seconds FI 60-seconds:** Comparing the chain and tandem schedules, both subjects displayed approximately the same decrease in the initial link. There were also decreases in the terminal links of the chain, but A-5 had a larger decrease which was probably due to the higher terminal link rate on the tandem control. The higher rate on the tandem for A-5 could have been the result of a sequence effect. The tandem stimulus was red. Since the terminal link of the preceding chain condition, in which animals characteristically respond at high rates, was also signalled by a red stimulus, A-5 might consequently have responded at a higher terminal rate on the tandem. Both subjects displayed similar overall rates of responding for the chaining condition, and they are very similar to the overall rates for the FI 60-second FI 90-second chain. This would suggest that with regard to response rates, neither chain was more reinforcing than the other.

Table 2 presents the mean response rates of the last 5 sessions for the non-paired brief stimulus control procedures. Since this condition provided an independent control for the chained schedules, the chaining data are also presented to facilitate comparison.

Rates of responding on the brief stimulus controls are very similar to those in the initial and terminal links of the chains, for both 60-90 and 90-60 conditions. The exception is that a higher rate appeared in the initial link of the BS^n FI 90-second
Table 2

A COMPARISON OF THE MEAN RESPONSE RATES FOR THE BRIEF STIMULUS AND CHAINED SCHEDULES

<table>
<thead>
<tr>
<th>Pigeon</th>
<th>Condition</th>
<th>Initial Link</th>
<th>Terminal Link</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-3</td>
<td>BS\textsuperscript{n} 60-90</td>
<td>7.71</td>
<td>48.70</td>
<td>29.45</td>
</tr>
<tr>
<td>A-5</td>
<td>chain 60-90</td>
<td>6.09</td>
<td>51.40</td>
<td>29.03</td>
</tr>
<tr>
<td>A-15</td>
<td>chain 60-90</td>
<td>6.67</td>
<td>46.03</td>
<td>27.40</td>
</tr>
</tbody>
</table>

|     | BS\textsuperscript{n} 90-60 | 15.58 | 54.57 | 30.81 |
| A-3 | chain 90-60 | 11.77 | 63.51 | 29.28 |
| A-5 | chain 90-60 | 12.61 | 49.40 | 26.92 |
FI 60-second schedule. The overall rates of responding on the brief stimulus schedules also replicated those of the chains.

Figures 1 and 2 present typical cumulative records for each bird from the tandem (t), chain (c), and brief stimulus (bs) schedules for the first and second phases of the experiment. The middle 10 reinforcements from the third session of the last 5 sessions appear. The pips indicate the completion of a component, and the pen reset upon the completion of the reinforcement cycle.

The tandem and chain records show the general lowering of response rates in the initial links of the chains. The chain and brief stimulus records for the 60-90 condition (Figure 1) show the low rate which occurred in the initial link, followed by a high rate in the terminal link. Patterning characteristic of FI schedules did not occur in both components: however, a scallop sometimes appeared in the terminal link after a change in the exteroceptive stimulus condition.

Patterning in both components, indicated by the arrows, sometimes occurred on chain FI 90-seconds FI 60-seconds (Figure 2). This was most generally characterized by a break-and-run pattern in the initial link, and a scallop in the terminal link. Subject A-15 had a more defined scallop in the terminal link, when it did occur. The record of subject A-3, for the BSn FI 90-second FI 60-second schedule, also shows that patterning sometimes occurred.
Figure 1

Typical cumulative records for tandem (t), chain (c), and brief stimulus (bs) schedules for FI 60-second FI 90-second conditions appear. The records were taken from the middle 10 reinforcements from the third session of the last 5 sessions. Pips indicate the completion of a component, and the pen reset upon the completion of the reinforcement cycle.
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Figure 2

Typical cumulative records for tandem (t), chain (c) and brief stimulus (bs) schedules for the FI 90-second FI 60-second conditions appear. The records were taken from the third session of the last 5 sessions. The middle 10 reinforcements appear. The pips indicate the completion of a component, and the pen reset upon the completion of the reinforcement cycle. The arrows indicate the occurrence of patterning in both components.
Table 3 presents a comparison of the response rates for chain and tandem FI 90-seconds FI 60-seconds, and FI 90-seconds FI 30-seconds, for subject A-15. When the frequency of primary reinforcement was increased in the terminal link from 60-seconds to 30-seconds, rates in the 90-second initial link of the chain increased from 12.61 to 21.65 responses per minute. The rate in the initial link of the tandem control showed an increase of 2.33 responses per minute. When tandem and chain FI 90-seconds FI 30-seconds are compared, there is a slight reduction in rate in the initial and terminal components on the chain.
Table 3

A COMPARISON OF TANDEM AND CHAIN RESPONSE RATES WHEN THE FREQUENCY OF PRIMARY REINFORCEMENT WAS INCREASED

<table>
<thead>
<tr>
<th>Pigeon</th>
<th>Condition</th>
<th>Sessions</th>
<th>Initial Link</th>
<th>Terminal Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-15</td>
<td>tandem 90-60</td>
<td>17</td>
<td>20.00</td>
<td>60.31</td>
</tr>
<tr>
<td></td>
<td>chain 90-60</td>
<td>15</td>
<td>12.61</td>
<td>49.40</td>
</tr>
<tr>
<td></td>
<td>tandem 90-30</td>
<td>15</td>
<td>22.33</td>
<td>53.09</td>
</tr>
<tr>
<td></td>
<td>chain 90-30</td>
<td>15</td>
<td>21.65</td>
<td>50.70</td>
</tr>
</tbody>
</table>

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DISCUSSION

The general results over the experimental conditions indicated a decrease in response rates in the initial link of the chains. Patterning sometimes occurred on chain FI 90-seconds FI 60-seconds, and the chained schedules were replicated in the essential features with the brief stimulus controls. When the frequency of primary reinforcement was increased in the terminal link, rate increases appeared in the initial link of the chain. However, rates also slightly increased in the initial link of the tandem control.

Two features of the data might provide support for a conditioned reinforcement interpretation. When the frequency of primary reinforcement was increased in the terminal link, the rate of responding increased in the initial link. The larger increase in the initial link of the chain, when compared to the slight increase on the tandem control, might indicate that the terminal stimulus was a conditioned reinforcer. These results would support the Autor (1960) and Herrnstein (1964) investigations, in which responding increased in the initial link when the frequency of primary reinforcement increased in the terminal link. However, at a methodological level, the reduction in the inter-reinforcement time still remains a possible confounding variable, and further experimentation over a wider range of schedule parameters is needed to determine its contribution.
A second factor which might support a conditioned reinforcement interpretation was the evidence of patterning on chain FI 90-seconds FI 60-seconds. This was a replication of the results obtained by Kelleher and Fry (1962) with three-component chains. They reported that although response rates decreased on the chain, with respect to the tandem control, patterning characteristic of a FI schedule occurred in the component preceding primary reinforcement. This indicated that the terminal stimulus was a conditioned reinforcer.

Although a conditioned reinforcement interpretation cannot be eliminated, there are some other factors that would seem to make it less likely. The non-paired brief stimulus controls produced response rates in the initial links similar to the chained schedules for both conditions in the first phase. This would seem to suggest that a stimulus never directly paired with primary reinforcement is capable of sustaining behavior in a manner similar to a stimulus which is paired with primary reinforcement, as in chained schedules. While it is possible that non-paired (trace) stimuli may possess reinforcing properties in some situations (Kendall, 1969), this would prompt a total reevaluation of the way in which a stimulus acquires reinforcing properties (Hendry, 1969). The pairing of a stimulus and primary reinforcement is usually a sufficient condition for endowing a stimulus with reinforcing effects (Kelleher and Gollub, 1962).

The similarity of the chain and brief stimulus conditions would also support the results obtained by Stubbs (1971). In
that study, the effects of paired and non-paired brief stimuli were compared for longer sequences of components, and the non-paired stimulus controlled behavior similar to the paired stimulus. The similarity of the effects of paired and non-paired stimuli has also been reported by de Lorge (1969) with DRL schedules.

A second factor which might argue against a conditioned reinforcement interpretation is that response rates decreased in the initial link across all chaining conditions, when compared to the tandem controls. If conditioned reinforcement was operating in the chains, an increase should have been expected. The presence of two reinforcing stimuli, a conditioned reinforcer and a primary reinforcer, should sustain a higher rate of responding than primary reinforcement alone. The decreases observed would support the results obtained by Crossman (1969) with fixed-ratio schedules, although he used the post-reinforcement pause as a dependent variable. Simple fixed-ratio schedules were compared to a two-component chain with fixed-ratio components. An increase in the post-reinforcement pause was reported on the chain, when compared to the simple fixed-ratio baseline, indicating a suppression-like effect. Eckerman and McGourty (1969) have also obtained suppressed rates of responding prior to the placement of response-produced stimuli in FI schedules. They interpreted their data as indicating that the response-produced stimuli were conditioned punishers for responding preceding their production.

A second interpretation of the data is that the production of a change in the exteroceptive stimulus conditions on a chained...
schedule functions discriminatively. That is, the stimuli in a chained schedule might function like an added-clock, as in simple FI schedules (Ferster and Skinner, 1957). An exteroceptive stimulus which changes in some systematic way since the passage of time may be added to FI schedules. The change in stimuli is called a clock. The change in stimuli usually occurs independently of responding, but it may be made response-dependent (Segal, 1962). The usual result of the addition of clock stimuli is to reduce responding below that of the single stimulus baseline (Segal, 1962; Kendall, 1972). The occurrence of reduced responding in the initial links in the present investigation might suggest that the stimuli on the chained schedules were serving as clock stimuli. The interesting possibility, however, is that it may not be necessary to require that a stimulus be present for the duration of a component to produce clock-like effects. This is suggested by the similar results with the brief stimulus controls.

If a chained schedule is regarded as an interreinforcement interval which is divided into two parts by a change in the exteroceptive stimulus conditions, the present results are similar to those of Farmer and Schoenfeld (1966a, 1966b). In their experiments, response-independent and response-dependent stimuli were placed into FI schedules at varying temporal lengths from primary reinforcement. Intrusion of the added stimulus early in the interval had little effect on responding. When the stimulus was placed later in the interval, the effect was to produce patterning in both segments of the FI which was divided by the
added stimulus. This suggests that the occurrence of patterning may not be dependent upon the reinforcing properties of the added stimulus, but rather the state of the preceding single stimulus baseline. Responding early in a FI schedule characteristically occurs at a low rate, hence, the added stimulus will have little or no effect. Later in the interval, when accelerated responding occurs, an added stimulus may modify the pattern of responding.

The exception to Farmer and Schoenfeld's (1966a, 1966b) results in the present investigation was the large reduction in response rates for one subject on chain FI 60-seconds FI 90-seconds. However, patterning characteristic of FI schedules did not occur in both components on this condition. When patterning occurred on chain FI 90-seconds FI 60-seconds, the pauses following the change in the exteroceptive stimulus conditions might have resulted from the fact that the change in stimuli always preceded a period of non-reinforcement (Stubbs, 1971).

The results of this study, while not definitive, suggest the extended investigation of chained and non-paired stimulus schedules. Perhaps they might best be studied in complex multiple schedules. A two component chain could occur in one component of the multiple, and the non-paired brief stimulus schedule could occur in the other component. This would not only provide the advantage of the conservation of experimental time, but would also allow for a more direct comparison of the two procedures in the same experimental session.
REFERENCES


