SELF-IMPOSED DELAYS OF REINFORCEMENT
IN CONJUNCTIVE SCHEDULES
by
Daniel M. McCarthy

A thesis submitted in partial fulfillment
of the requirements for the degree
of
MASTER OF SCIENCE
in
Psychology

Approved:

UTAH STATE UNIVERSITY
Logan, Utah
1972
ACKNOWLEDGMENTS

I would like to express my gratitude to my committee, Drs. Richard B. Powers, Carl D. Cheney, and J. Grayson Osborne, for their advice and encouragement throughout the conduct of this research.

Daniel M. McCarthy
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>REVIEW OF LITERATURE</td>
<td>4</td>
</tr>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Dews’ Hypothesis</td>
<td>5</td>
</tr>
<tr>
<td>Delay of Reinforcement</td>
<td>7</td>
</tr>
<tr>
<td>Conjunctive Schedules</td>
<td>16</td>
</tr>
<tr>
<td>STATEMENT OF THE PROBLEM</td>
<td>21</td>
</tr>
<tr>
<td>METHOD</td>
<td>23</td>
</tr>
<tr>
<td>Subjects</td>
<td>23</td>
</tr>
<tr>
<td>Apparatus</td>
<td>23</td>
</tr>
<tr>
<td>Procedure</td>
<td>24</td>
</tr>
<tr>
<td>RESULTS</td>
<td>28</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>41</td>
</tr>
<tr>
<td>SELECTED BIBLIOGRAPHY</td>
<td>45</td>
</tr>
<tr>
<td>VITA</td>
<td>49</td>
</tr>
</tbody>
</table>
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Summary of each subject's program. Prior to baseline conditions, each S received at least 100 reinforcers on a continuous reinforcement schedule.</td>
<td>27</td>
</tr>
</tbody>
</table>
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Time and response requirements for FI and Conj schedules. Unfilled blocks indicate responses which do not produce a reinforcer. The small filled blocks represent responses which produce the reinforcer. The larger filled blocks represent reinforcers. The portion of the interval to the left of the dashed, vertical line denotes the portion of the interval in which responses are ineffective, the &quot;dead&quot; portion of the interval. The dashed, horizontal line indicates the delay between the final response and reinforcement.</td>
<td>25</td>
</tr>
<tr>
<td>2. Cumulative records of the final session on FI 100 sec (A), the 33rd session on Conj 0% (B), and the 36th session on Conj 0% (C) for rat M6. Note the scalloped pattern, positive accelerations, in A and the negative accelerations in B and C.</td>
<td>29</td>
</tr>
<tr>
<td>3. Cumulative records from the final session on Conj 0% (A), from session 19 on Conj 95%, and from session 31 on Conj 95% for rat M10. Note the negatively accelerated rates in and the tendency toward more positive accelerations in B and C.</td>
<td>31</td>
</tr>
<tr>
<td>4. Response distributions for M7 and M10. The percentages were derived from responding cumulated over the last five days on each schedule condition. Note the positive acceleration in Conj 95% and FI 100 sec, and the negative acceleration in Conj 0% and Conj 75%.</td>
<td>33</td>
</tr>
<tr>
<td>5. Post-reinforcement pause distributions for M6 and M10. The distributions were derived from the last five days on each schedule condition. The dark vertical line indicates the mean pause length.</td>
<td>36</td>
</tr>
<tr>
<td>6. Response rate as a function of median delay of reinforcement. The mean rate and median delay were averaged over the last five days under each schedule condition.</td>
<td>38</td>
</tr>
</tbody>
</table>
ABSTRACT
Self-Imposed Delays of Reinforcement in Conjunctive Schedules
by
Daniel M. McCarthy, Master of Science
Utah State University, 1972
Major Professor: Dr. Richard B. Powers
Department: Psychology

This experiment examined the role of delays of reinforcement in producing the response pattern generated by fixed interval (FI) schedules. Conjunctive schedules which required one response and maintained a 100 sec interreinforcement interval were used. These schedules permitted a variable delay of reinforcement to separate the last response in each interval from reinforcement. The maximum delay was specified, however, by specifying the percentage of the interval which must elapse before responses counted toward reinforcement. Maximum delays of 100, 95, 75, 50, 25, 5 and 0 seconds were examined and their effects on response rate, response distribution, and post-reinforcement pause were measured.

The study generated the following results: (1) Although the maximum delay possible was specified, this delay was seldom taken; interim responses were emitted and the delay was shortened. Longer median delay of reinforcement produced lower response rates.
(2) Fixed interval schedules produced the shortest post-reinforcement pauses. When the schedule allowed longer delays the pause became longer. These changes are seen in overall distributions and only slightly affect the mean pause length. (3) When no delays were possible, e.g. on FI 100 sec, the distribution of pauses within the interval was positively accelerated. With schedules which permitted delays the distributions became less positively accelerated. Generally, the longer the delay of reinforcement, the more negatively accelerated the response distribution within the interval.

These data indicate that the delay of reinforcement disrupts the FI schedule performance. Longer delays lower the rate, lengthen the pause and eliminate the pause. Dews, in "The effects of multiple S^A periods on responding on a fixed-interval schedule," Journal of the Experimental Analysis of Behavior, 1962, 5, 369-374, suggests that the cumulation of delays of reinforcement produces the scalloped pattern. This experiment suggests that this is not the case. Even short delays, e.g. less than 8 sec, disrupt the scalloped pattern. These data suggest that the behavior occurring at the moment of reinforcement, rather than merely the delay of reinforcement per se, determines FI schedule performance.
INTRODUCTION

In a fixed interval (FI) schedule, the first response emitted after a fixed time period has elapsed is reinforced. The fixed interval is usually initiated by the termination of reinforcement, and responding prior to the termination of the interval has no programmed consequences. Performance under this schedule is characterized by: (1) a post-reinforcement pause and (2) a positive acceleration to a high terminal rate, sometimes referred to as a "scalloped" pattern (Ferster and Skinner, 1957). The present research examined factors responsible for this response pattern.

Fixed interval schedules are composed of the following contingencies: (1) each reinforcer is contingent upon a requirement of one response; (2) a fixed time requirement, the interreinforcement interval, which specifies the minimum time between reinforcements is maintained; (3) the reinforcer is delivered immediately after the effective response has been made; (4) another contingency specifies the portion of the interreinforcement interval which must elapse before the response requirement can be met, the "dead" portion of the interval. The entire interreinforcement interval must elapse on FI schedules before reinforcement becomes available; hence responses made during the interreinforcement interval are "wasted," that is, produce no programmed consequences.

Another schedule which can be defined in terms of these four
contingencies is the conjunctive schedule. Ferster and Skinner (1957) define a conjunctive schedule as one in which two contingencies, a temporal contingency and a response contingency, must be met before reinforcement can be obtained. This schedule does not necessarily specify any particular sequence in which these requirements must be completed. Hence, no "dead" portion of the interval is specified. It is possible, then, for the response requirement to be completed during the interreinforcement interval, therefore, before the temporal contingency elapses. In this case the reinforcer is delivered, independent of further responding, when the interval elapses (Powers, 1968; Shull, 1970, 1971; and Morgan, 1970).

A conjunctive schedule which maintains a constant interreinforcement interval and requires only one response can be used to investigate fixed interval performance. The portion of the interreinforcement interval during which responses produce no programmed consequences can be manipulated. If no "dead" portion of the interval is specified, 0% of the interreinforcement interval is dead; the schedule is the same as that discussed by Powers (1968), Shull (1970, 1971) and by Morgan (1970). If the entire interval (100% of the interval) is specified as the "dead" portion, then the schedule is a fixed interval schedule. Thus, by manipulating the length of the "dead" portion of the interval from 0% to 100% of the interreinforcement interval, conjunctive schedules can be used to approximate fixed interval contingencies, hence can be used to investigate FI schedule characteristics.
This procedure, however, introduces variable time periods separating responding from reinforcement which can be analyzed as delays of reinforcement. The delay of reinforcement is the interval between the last response emitted during the interval and the delivery of the reinforcer. The maximum delay of reinforcement can be limited by specifying the portion of the interval which must elapse before the response contingency can be met. Thus, the conjunctive schedule which specifies that 100% of the interval elapse before the response contingency can be met, necessarily limits the delay interval between response and reinforcement to zero seconds. This schedule is a fixed interval schedule. A conjunctive schedule which specifies that 25% of the interval elapse before a response can produce reinforcement necessarily limits the maximum delay of reinforcement to 75% of the fixed interreinforcement interval. The actual delay of reinforcement can vary, however, and will be determined by the place in the interval that the subject emits his last response. By specifying the "dead" portion of the interval; that is, the percentage of the interval during which responding does not count, the conjunctive schedule limits maximum delay length while holding the interreinforcement interval constant.

The present study manipulated the percentage of the interval during which responses did not count toward reinforcement. Changes in response rate, post-reinforcement pause length, and response patterns were examined when the "dead" percentage of a 100 second conjunctive schedule was varied.
REVIEW OF LITERATURE

Introduction

Fixed interval (FI) schedules generate response patterns described either as "break-and-run" (Cumming and Schoenfeld, 1958; Sherman, 1959; Schnieder, 1969) or as "scalloped" (Ferster and Skinner, 1957; Dews, 1962, 1965a, 1965b, 1969). In both break-and-run and scalloped fixed intervals, reinforcement is followed by a pause (post-reinforcement pause), but the response pattern following the pause differs. When the pause terminates and responding begins, in break-and-run fixed intervals, the response rate is consistent and moderately high. Thus, the response pattern is relatively even, with few fluctuations and with little or no acceleration from the time responding begins until the interval terminates and reinforcement is produced. The scalloped pattern, on the other hand, is characterized by a positively accelerating, high response rate which follows the pause and coincides with the delivery of reinforcement. Thus, the first few responses of the fixed interval occur at a low rate, but as the interval progresses the rate increases, with reinforcement being produced by high rate responding. Hence, responding in break-and-run fixed intervals is consistent, uniform, and moderately rapid; whereas, in scalloped intervals responding is positively accelerated, and shifting from very low to very high rates within
the interval. In both cases, a post-reinforcement pause precedes the first response in each interval. The present research does not necessarily concern break-and-run, fixed interval performance; rather it deals with the post-reinforcement pause and the response pattern in scalloped, fixed interval responding.

Dews' Hypothesis

Dews (1962) examined the notion that the scalloped pattern in FI schedules is due to response chaining. This notion suggests that one response in the interval serves as a discriminative stimulus for the emission of the next response. In particular, low rate responding early in the interval is a discriminative stimulus occasioning the shorter latency of the next response. This response, in turn, occasions the next response with an even shorter latency. Thus, the cumulation of responses each with successively shorter latencies, produces the positive acceleration or scallop. If, then, the notion of chaining holds and responding is prevented at one point in the interval, the entire chain will be disrupted. In other words, if responding is prevented during the interval, the scalloped effect should not appear. Dews (1962) examined a fixed interval schedule which was composed of alternating houselight off (S\text{A}) and houselight on (S\text{D}) periods of equal length. With this schedule, Dews noted that in the S\text{A} periods little or no responding occurred, whereas in the S\text{D} periods responding occurred. Responding during a particular S\text{D} period, however,
was related to the position of that $S^D$ period in the interval. Responding was low in the $S^D$ periods immediately following reinforcement, but the $S^D$ response rate increased as the $S^D$ periods came nearer to the end of the interval. Thus, the positive acceleration or scallop survived the "disruptions" imposed by the $S^\Delta$ periods. From this experiment Dews concluded that since the FI scallop is not destroyed when the conditions necessary for response chaining are eliminated, the scallop cannot be the product of a response chain composed of progressively shorter inter-response times. Dews replicated this phenomenon several times: with primates (1965a); with different patterns of interruption, parameters, and stimuli (1965b); with short $S^D$ periods probing continuous $S^\Delta$ periods (1966a); and with occasional omissions of food presentations (1966b). Dews (1970) refers to the stability of the FI scallop in the presence of disruptions as the Cheshire cat phenomenon: the scallop remains even though the larger portion of the schedule, and responding associated with it, has been removed.

To replace the response chaining hypothesis, Dews (1962) suggests that the positive acceleration in fixed interval schedules is due to the effect of a retroactive, rate-enhancing gradient of reinforcement. The effect of reinforcement is exerted maximally upon the response which is nearest the delivery of reinforcement, but the reinforcing effect goes back further than the one response. All responses are strengthened, although not to the same degree. The effect of the reinforcer decreases as the function
of retroactive distance from reinforcement. The further in time a response is separated from reinforcement the less it is strengthened by reinforcement. Thus, in fixed interval schedules the high rate immediately preceding reinforcement is produced by the maximum, response-strengthening effect of reinforcement. The lower rates earlier in the interval are also produced by the strengthening effect of reinforcement. However, the delay of reinforcement, that is, the interval between a response and reinforcement, lessens the effect of the reinforcer. Thus, because the responses early in the interval are strengthened less than those emitted later in the interval, they occur less frequently. Hence, the shift from low to high rates as the interval progresses is hypothesized to be a function of the increasing strength of reinforcement as the interval progresses. This notion, then, suggests that the delay of reinforcement is a critical factor in the development of the FI scallop.

Delay of Reinforcement

Catania (1971) describes a series of experiments in which specific response sequences in a two-key situation were reinforced. With this procedure reinforcement was programmed for a particular series of alternations between keys. In this manner the role of a response on one key in producing the reinforcer could be assessed even though additional responses were required and were emitted on the other key. Thus, the procedure examined
the strengthening effect of a reinforcer upon a response separated in time (by other responses) from the reinforcer. The strength of the alternation sequence was assessed in terms of the reinforcement effect upon individual responses making up that sequence. Thus, the retroactive effect of reinforcement was tested. Catania suggested that although only the terminal response is reinforced, all responses in the sequence are strengthened. In maintaining the strength of sequential responding, a reinforcer spreads its effect back in time, not merely to the one response temporally contiguous with reinforcement, rather to a large number of responses separated in time from reinforcement. Catania (1971) supports Dews' (1962) hypothesis and provides an example of the effects of delayed reinforcement maintaining responding. Catania's (1971) study, too, suggests further examination of the research in delayed reinforcement.

Delay of reinforcement has been found to weaken responding. Interposing an interval between a response and reinforcement lowers rates of responding, increases pause lengths, and is less preferred in comparison to schedules which provide immediate reinforcement (Skinner, 1938; Perin, 1943; Dews, 1960; Chung, 1965; Chung and Herrnstein, 1967; Neuringer, 1969; Powers and Edwards, 1971). Responding, however, can be maintained by delayed reinforcement. For example, Dews (1960) examined the performance of pigeons on a schedule which required only one response per reinforcement. Under these schedule contingencies only one response
was required to initiate the delay of reinforcement interval. Thus, the first response following a reinforcer initiated the delay interval, which determined the minimum length of the inter-reinforcement interval. Reinforcement was delivered at the end of an interreinforcement interval if a response had been made: (a) independent of whether or not further responding occurred, in one case; and (b) only if no further responding occurred during the delay interval in the second case. Dews (1960) found: (1) that both schedules maintain responding, albeit low rate responding; (2) that when only one response is required and no contingencies are in effect for further responding, responses having no programmed effect are emitted and the delay between a response and reinforcement is shortened; and (3) that adding a differential reinforcement of other behavior (DRO) contingency, which restarts the delay interval with each response during the interval, further decreases the response rate. In this last case, the organism is punished for responding during the delay interval by postponing reinforcement. In addition, when the schedule required a response and delay, both with and without a DRO contingency, maintained responding, whereas delivery of non-contingent reinforcement with the same frequency of reinforcement failed to do so.

Ferster (1953) demonstrated that responding can be maintained with delays up to 60 seconds. In this case, the subjects (pigeons) were initially trained on a variable interval (VI) schedule, and
during the delay period, the chamber was completely darkened (blackout) to prevent responding. Even with the 60 second delay the VI response rate was maintained in one of four birds. Delays of 120 seconds, however, almost completely eliminated responding. Subsequently, all four pigeons underwent extinction, were retrained on a VI schedule, and given special training with delays of reinforcement. This special training consisted of progressively lengthening the delay interval. Following this training the VI 60 sec blackout 60 sec response rate was comparable to the standard VI 60 sec rate for three of four birds. The lack of a rate decrease with a 60 sec delay can be accounted for by two factors. First, the delay interval was gradually increased during training, such that the responding is probably due to a special training procedure. Second, the introduction of delay stimulus (blackout) functionally converted the simple VI-delay schedule to a chain VI-DRO schedule. Thus, the blackout probably served as a conditioned reinforcer sufficient to maintain the VI responding, while the DRO performance was maintained by the delivery of reinforcement at the end of the differential (blackout) stimulus.

Chung (1965) and Chung and Herrnstein (1967) used a concurrent, two key situation to examine delay of reinforcement effects. In both studies, equal VI schedules on either key produced a blackout which was followed by the delivery of food reinforcement. The delay length, blackout duration, was varied
over a wide range and was compared to a standard delay duration. In both studies, overall response rates varied inversely with the length of the delay; and relative response rate changes approximated changes in rates of reinforcement. Both Chung (1965) and Chung and Herrnstein (1967) suggest that the decrease in response rate is due to the decrease in reinforcement frequency. The relationship between response rate and rate of reinforcement are more thoroughly discussed elsewhere (see: Catania, 1966; Morse, 1966; and Herrnstein, 1970). Using a concurrent chain schedule, Neuringer (1969) examined the relationship between delay of reinforcement and schedule preference. In this study, the response rates in the initial links of the chain schedules on either key reflected the pigeons' preference. While the initial link of each schedule was VI 90 sec, the terminal link, the time-to-reinforcement, was either an FI schedule on one key or a blackout and response-independent reinforcement on the other. In the first experiment, the time-to-reinforcement, that is, the duration of the terminal link of the chain schedule, was equal on both keys. In this case, there was a slight preference (55%) shown for the FI rather than the delay contingencies. Next, the time-to-reinforcement was systematically varied. The FI duration and delay interval were equal, however. The response rate in the initial link varied inversely with changes in the time-to-reinforcement. When different times-to-reinforcement were programmed for each key, e.g., a long FI and short delay interval or vice versa, the link
maintaining the shortest time-to-reinforcement was preferred. Finally, the effect of the blackout was assessed by: (1) adding a continuously illuminated houselight thus having no blackout albeit darkened keys; and (2) signalling the end of the delay interval and requiring a response to produce reinforcement. These procedures demonstrated that the slight preference for the FI in the initial experiment was due to the blackout. When there was no blackout, and again when the response contingencies were comparable, i.e., when a post-delay response was required, there was no preference (50%) for either set of contingencies. This study demonstrates: (1) that the rate of response is inversely related to the length of the delay of reinforcement, and (2) that the blackout procedure does exert an effect on schedule preference because, in the absence of a blackout, "pigeons demonstrate little or no preference in their choices between a delayed reinforcement and a temporally equal, fixed interval schedule of reinforcement" (Neuringer, 1969).

Thus, the use of a blackout to prevent responding during the delay interval produces serious effects. First, blackouts affect schedule preferences; schedules with no blackouts are more likely to be chosen than schedules which maintain blackouts, even though reinforcement densities are equal. Second, the termination of the blackout is paired with reinforcement, thus the blackout functionally converts the initial schedule to a chain schedule. The blackout then can be considered a potential
conditioned reinforcer. Third, despite being correlated with the production of reinforcement blackouts have been shown to maintain responding when they are produced in lieu of food reinforcement (Neuringer and Chung, 1967). In this study, responding on a VI schedule produced either a food reinforcer or a blackout. The percentage of intervals which was terminated by the production of a blackout was manipulated. Blackouts were found to generate the effects similar to those of food reinforcers when the proportion of blackouts to food reinforcers was small. Neuringer and Chung's (1967) study, too, suggests that blackouts critically affect responding. From these studies we can conclude that despite their effectiveness in preventing responding during the delay interval, thereby equating the actual and the specified delays, blackouts adversely affect the study of delayed reinforcement.

Wood (1968) examined some delay of reinforcement factors as they affect VI schedules. Specifically, Wood examined the procedural contingencies involved in producing the delayed reinforcer, that is, the contingencies necessary to initiate and maintain the delay interval. First of all, when the delay interval is specified and responding during the interval restarts the interval (Dews, 1960), the absolute length of the delay interval, the interval between a response and reinforcement, is constant. However, because responses generally are emitted during the interval, the interreinforcement interval lengthens with each interim response and the overall frequency of rein-
forcement decreases. Wood (1968) demonstrated that although other-than-lever pressing behaviors are always reinforced, this contingency forces the organism to alter his response pattern, in the absence of stimulus changes, from a high or moderate rate (VI) to a zero rate in order to produce the reinforcer. Thus, adding a DRO contingency forces the organism to make a difficult rate alteration, which often results in a decreased reinforcement frequency. Second, when a DRO contingency is not specified the delay interval begins with a response and, independent of further responding, terminates with reinforcement. This procedure, however, permits the actual length of the delay interval to vary because each succeeding interim response shortens the interval between that response and the reinforcer. Although this type of delay interval does not force a rate change, and does not usually decrease reinforcement frequency, and does not introduce differential stimulus conditions, it cannot specify the actual delay interval.

In addition to elucidating these procedural difficulties, Wood (1968) varied the length of the delay interval, in the absence of a blackout, on a VI schedule. In essence, he replicated Dews' (1960) findings, as well as those of Chung (1965) and Chung and Herrnstein (1967): (1) response rates vary inversely with delay length, (2) response rates were considerably lower when a DRO contingency was required than when the DRO contingency was absent, and (3) response rates tend to vary directly with reinforcement rates.
Powers and Edwards (1961) manipulated the length of a DRO interval in a tandem FI-DRO schedule and measured changes in overall response rate, post-reinforcement pause length, and response pattern. They found that as the length of the DRO increased, the response rate decreased, the pause duration became longer, and the pattern of responding became progressively more negatively accelerated. Again, as the length of the DRO interval increased, the frequency of reinforcement decreased.

In summary, the effects of delays of reinforcement on responding are consistent: delay of reinforcement weakens responding. (1) When the actual interval between a response and reinforcement is specified by preventing interim responding either by using blackout or by maintaining a DRO contingency, the response rate decreases as the length of the interval increases. (2) The same function is produced when the maximum delay is specified yet the actual delay is free to vary. (3) As the length of the delay interval increases and response rates decrease, the rate of reinforcement decreases. Thus, reinforcement frequency is suggested to be a factor responsible for rate decreases. (4) Using a blackout and special training procedures, rate decreases can be prevented even in the event of relatively long delays. In general, though, the main effect of delayed reinforcement is a response decrement which is related to the length of the delay.

The effects of reinforcement delays upon response rate lend support to Dews' (1962) hypothesis. The delay between the last
response in an interval and the reinforcer as a factor affecting fixed interval response patterns must be assessed as a test of Dews' (1962) hypothesis. Very short delays should produce slight, if any, effects on the within-interval response pattern. Longer delays should produce greater pattern changes. The effect of the actual delay, rather than a specified delay period interrupted by interim responses, must be examined in order to test the Dews' (1962) notion. The constancy of the interreinforcement interval appears to be a prerequisite for scalloped responding (Catania and Reynolds, 1968; Dews, 1970). The studies discussed above examined several constant delays of reinforcement in a schedule which varied the frequency of reinforcement. Dews (1960) suggests a procedure which permits delays, however variable, yet maintains a fairly constant interreinforcement interval and utilizes no blackout or DRO contingencies. This schedule requires one response to initiate an interval at the end of which reinforcement is delivered. Other responses can be emitted, but they have no programmed consequences, yet functionally serve to shorten the delay interval, the interval between a response and reinforcement. This schedule is a type of conjunctive schedule.

Conjunctive Schedules

Ferster and Skinner (1957) define a conjunctive schedule as one in which two contingencies, a response requirement and a temporal requirement must be met before reinforcement can be attained. This definition does not specify the order in which
the contingencies must be met. The response requirement can be
met before the temporal requirement, the interreinforcement
interval, has elapsed. Thus, this schedule can permit examination
of response contingencies and delay of reinforcement effects
upon constant interreinforcement intervals. Also, this basic
schedule is useful in testing Dews (1962) hypothesis because
the fixed interval schedule is a special case of the conjunctive
schedule. Fixed interval schedules maintain response and
temporal requirements but they require that the temporal require­
ment is met before the response requirement can be made and
reinforcement delivered.

Herrnstein and Morse (1958) examined the effect of several
response requirements on a 15 minute interreinforcement interval
conjunctive schedule. They found that beyond a certain ratio
requirement, as the response requirement increased the rates
decreased and the interreinforcement interval lengthened. They
noted that the conjunctive response rate was lower than comparable
FI schedules. Hitzing and Kaye (1969) used a 3 minute interval
and ratio requirements ranging from 1 to 125 responses. These
researchers found the rates increased as the response ratio
increased, up to a ratio of 125, when responding stopped alto­
gether. Hitzing and Kaye suggest that these contradictory results
may be due to the differences in interreinforcement intervals.
Both studies demonstrate that conjunctive schedules maintain
an overall lower rate lower than comparable FI schedules.
These schedules, however, did not permit a delay to occur between
the last response and reinforcement. If the ratio requirement was completed prior to the end of the interval, an additional response was required at the end of the interval to activate reinforcement.

Powers (1968), Shull (1970, 1971), and Morgan (1970) investigated conjunctive schedules which did not necessarily require a response immediately preceding reinforcement. These schedules require the emission of only one response; that the one response can occur at any point in the interval. These schedules are procedurally similar to the schedule maintaining no DRO contingency, described by Dews (1960). When the response ratio is met, the reinforcer is delivered when the interreinforcement interval terminates independent of further responding. The delay of reinforcement, then, is that interval elapsing between the completion of the response requirement and the delivery of the reinforcer, given that no further responding occurs. Should additional responses occur, they have no programmed consequences; however, they shorten the delay. The delay is, then, the interval between the last response made and the delivery of reinforcement. These studies demonstrate: (1) that one-response conjunctive schedules can maintain stable responding, despite the variable delays of reinforcement; (2) responding on a conjunctive schedule is considerably less frequent than in comparable FI schedules, and does not show a positively accelerating response rate (scallop). Rather, the pattern consists typically of a pause after reinforcement, followed by a burst of several
responses, and a second pause until reinforcement. Hence, the response pattern is negatively accelerated. Response rates were considerably lower, however, when reinforcements were completely non-contingent (Shull, 1971), despite the similarity of the response pattern. Shull (1970, 1971) and Morgan (1970) examined the post-reinforcement pause relations on conjunctive and fixed interval schedules and found that there is little difference in mean or median pause length on either schedule. In one condition of the experiment, Shull (1970) examined the role of exteroceptive stimulus changes in conjunctive schedules. When the bird terminated the post-reinforcement pause and thus completed the response requirement, the color of the key changed from orange to blue and remained blue until reinforcement. Thus, Shull (1970) provided his subject with feedback information about the completion of the response requirements. Changing the key color with the termination of the pause did not produce performance different from that produced without a changing key-color. Thus, response rates and pause lengths were independent of exteroceptive stimulus change. When response-independent reinforcement was provided (Shull, 1971) mean pause length increased due to the absence of responding in some intervals; and (4) Morgan (1970) examined the delay of reinforcement interval and found that his subjects (rats) tended to respond later in the interval, thus effectively producing short delays.

Using a conjunctive schedule, then, one can test Dews'
(1962) gradient of delay hypothesis. The schedule maintains a constant interreinforcement interval and a response requirement comparable to FI, and permits variable delay of reinforcement without other compounding effects, e.g., blackouts. In addition, several dependent variables can be utilized (response rate, response pattern, and post-reinforcement pause) to assess the relationship between conjunctive and fixed interval contingencies. The effect of various, actual delays of reinforcement in constant interval, one-response conjunctive schedules can test Dews' (1962) hypothesis. If the actual interval separating the last response from reinforcement is recorded a distribution of actual delays will be produced. Relating the length of the actual delay to interval performance will test Dews' (1962) notion, since a variety of delays will be generated and a variety of response patterns will be produced. Whether or not delays alter response patterns from scallops to more negatively accelerated patterns can be seen as a consequence using conjunctive schedules to investigate FI performance.
STATEMENT OF THE PROBLEM

Dews (1962) suggests that the positively accelerating response rate maintained by fixed interval schedules is due to the operation of a retroactive, rate-enhancing gradient of reinforcement. Responses further away in time from reinforcement are strengthened less than those responses more temporally contiguous with reinforcement. Thus, the cumulative effect of many delays of reinforcement determines response rate within a given fixed interval. This hypothesis implies that the temporal distance separating that response from reinforcement, the delay of reinforcement, determines the probability that a response will occur at that point in time in future intervals. Therefore, in a given interval the pattern of the responses within that interval is determined by the changes in response probability which vary as an inverse function of the temporal distance from reinforcement. Thus, since longer delays of reinforcement generate lower response rates, responding early in the interval is not likely. As the interval progresses, the time-to-reinforcement shortens and the probability that a response will occur increases, hence, the response rate increases. This relationship between delay of reinforcement and response probability, according to Dews (1962) produces the fixed interval scalloped pattern of responding.

The present study examines Dews (1962) notion. If the res-
ponse pattern found with FI schedules is the product of various delays of reinforcement, changes in length of the delay should produce changes in the response pattern. In a constant interval schedule short delays of reinforcement should produce only slight changes in the scallop; longer delays should further alter the scallop. When only short delays occur, most of the scallop should remain intact; the short delays should have their effect only on those few responses immediately prior to reinforcement. The present study uses conjunctive schedules which approximate fixed interval contingencies yet permit variable delays of reinforcement to study FI performance. The effects of the variable delays on post-reinforcement pause, response rate, and response pattern are examined as a test of Dews' (1962) hypothesis.
METHOD

Subjects

Five female rats of the Long-Evans strain served as subjects. These rats were littermates, approximately 90 days old, and were naive at the beginning of the experiment. The rats were deprived of food; three were maintained at 85% of their ad lib weight. A fourth rat (M7) was maintained at 80% of her ad lib weight during the baseline sessions in an attempt to increase response rates. The fifth rat was never deprived and served as a guide from which to adjust for the growth rate of the deprived rats. Water was continuously available in each rat's home cage. Maintenance rations were placed in the home cages at the completion of each session.

Apparatus

A standard operant chamber, placed inside a sound attenuating box, was located in a room separated from the electromechanical programming equipment. A blower circulated air and provided masking noise. A nose operandum (Crossman, 1963) which required approximately a 12 gram lift across 3 mm was used. Baseline sessions were 60 min in length and typically terminated with from 30 to 35 reinforcers. Subsequent sessions terminated with the delivery of the twenty-fifth reinforcer or after 45 minutes had elapsed, whichever came first. The fixed time requirement
in the conjunctive schedules was 100 sec and was divided into ten class intervals of 10 sec each. Responses falling in each interval were cumulated over the entire session. Post-reinforcement pauses, likewise, were counted in 10 sec class intervals. A printout counter recorded the time in seconds between the terminal response in each interval and the delivery of a reinforcer.

Procedure

Figure 1 describes the conjunctive schedule percentage notation, illustrates the response requirement for both fixed interval and conjunctive schedules, and demonstrates how a delay between a response and reinforcement can occur.

Each of the conjunctive schedules studied had a requirement of 100 seconds and one response. The percentage notation attached to each conjunctive schedule denotes the percentage of the interval during which responses produce no consequence, that is, the portion of the interval that is "dead." For example, with the conjunctive 0% schedule the first response made after the interval has begun produced the reinforcer that was delivered at the end of the 100 sec interval, regardless of whether or not another response has been made. With the conjunctive 25% schedule, the first response made after 25 sec of the 100 sec interval produced the reinforcer delivered when the interval terminated. Since reinforcement was available only at the end of the interval, long delays between response and reinforcer were possible.
Figure 1. Time and response requirements for FI and Conj schedules. Unfilled blocks indicate responses which do not produce a reinforcer. The small filled blocks represent responses which produce the reinforcer. The larger filled blocks represent reinforcers. The portion of the interval to the left of the dashed, vertical line denotes the portion of the interval in which responses are ineffective, the "dead" portion of the interval. The dashed, horizontal line indicates the delay between the final response and reinforcement.
Fl 100

CONJ 95 %

CONJ 25 %

100 SEC
Each subject was magazine trained and shaped to lift the operandum and received at least 100 reinforcers on a continuous reinforcement schedule before being placed on the baseline schedule. Table 1 summarizes the schedule manipulations and number of sessions for each subject.

Table 1. Summary of each subject’s program. Prior to baseline conditions, each S received at least 100 reinforcers on a continuous reinforcement schedule.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Baseline Schedules</th>
<th>Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td>M6</td>
<td>FI 100</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Conj 0%</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Conj 50%</td>
<td>49</td>
</tr>
<tr>
<td>M7</td>
<td>FI 100</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Conj 5%</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Conj 75%</td>
<td>49</td>
</tr>
<tr>
<td>M9</td>
<td>Conj 25%</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Conj 5%</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Conj 75%</td>
<td>49</td>
</tr>
<tr>
<td>M10</td>
<td>Conj 0%</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Conj 95%</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Conj 50%</td>
<td>49</td>
</tr>
</tbody>
</table>
RESULTS

The FI 100 sec performance of M6 and M7 was characterized by positively accelerated response distributions and high rates. Cumulative record A in Figure 2 is representative of final performance on FI 100 sec for M6. The Conj schedules generated considerably lower rates and more negatively accelerated response distribution. Cumulative records B and C in Figure 2 show the effects of Conj 0% in lowering overall rates, lengthening the post-reinforcement pause, and replacing the scalloped pattern with a negatively accelerated response pattern. Cumulative records in Figure 3 demonstrate the converse effect. Cumulative record A shows performance on Conj 0% after 50 sessions. Cumulative record B and C show performance on Conj 95% after 19 and after 31 (final) sessions. Note the shift from negatively to more positively accelerated response rates, from low to high rates, and from longer to shorter pauses when the schedule was changed from Conj 0% to Conj 95%.

Figure 4 shows response distributions for subjects M7 and M10 on Conj 0%, 75%, 95%, and FI 100 sec schedules. These distributions were cumulated over the last five days of each schedule and represent typical performance on those schedules. Note the negative acceleration in Conj 0% and the positive acceleration in Conj 95% and FI 100 sec. The intermediate Conj values, i.e., Conj 5%, Conj 25%, Conj 50%, and Conj 95%,
Figure 2. Cumulative records of the final session on FI 100 sec (A), the 33rd session on Conj 0% (B), and the 36th session on Conj 0% (C) for rat M6. Note the scalloped pattern, positive accelerations, in A and the negative accelerations in B and C.
Figure 3. Cumulative records from the final session on Conj 0% (A), from session 19 on Conj 95%, and from session 31 on Conj 95% for rat M10. Note the negatively accelerated rates in and the tendency toward more positive accelerations in B and C.
Figure 4. Response distributions for M7 and M10. The percentages were derived from responding cumulated over the last five days on each schedule condition. Note the positive acceleration in Conj 95% and FI 100 sec, and the negative acceleration in Conj 0% and Conj 75%.
generated responding which was intermediate to Conj 0% and FI 100 sec responding.

The distribution of post-reinforcement pauses varied as a function of the "dead" percentage of each schedule. Figure 5 illustrates this relationship. Post-reinforcement pauses were longer on Conj 0% than on Conj 50%. The Conj 95% pause distribution approximated that of FI 100 sec. Thus, the FI 100 sec schedule produced the shortest post-reinforcement pause; as the schedule became more unlike FI 100 sec, i.e., changed from Conj 95% to Conj 50% and to Conj 0%, the pause lengthened. This change is represented in the total distribution, the mean pause varies only slightly. The median, actual delay of reinforcement (MD) is given for each condition.

The overall response rate on each schedule is an indirect function of the delay of reinforcement. The longer the interval between a response and reinforcement, the lower the response rate. Figure 6 shows the mean response rate for the last five sessions on each schedule as a function of the median delay of reinforcement for those sessions. This figure also illustrates the massive, rate-depressing effect of relatively short (2 to 8 sec) delays of reinforcement.

In sum, these results indicate that response rate, post-reinforcement pause length, and overall response pattern are affected systematically by delays of reinforcement. Longer delays of reinforcement produce lower rates, longer pause length,
Figure 5. Post-reinforcement pause distributions for M6 and M10. The distributions were derived from the last five days on each schedule condition. The dark vertical line indicates the mean pause length. In each histogram N represents the total number of pauses comprising the distribution; M.D. indicates the median, actual delay of reinforcement for that distribution.
M 6
FI 100
N = 123
M.D. = 0"

M 10
CONJ 95 %
N = 124
M.D. = 3"

CONJ 50 %
N = 129
M.D. = 2"

CONJ 0 %
N = 121
M.D. = 2"

CONJ 50 %
N = 130
M.D. = 3"

CONJ 0 %
N = 124
M.D. = 6"
Figure 6. Response rate as a function of median delay of reinforcement. The mean rate and median delay were averaged over the last five days under each schedule condition.
and more negatively accelerated response distributions. The more the schedule approximates FI, the shorter the post-reinforcement pause, the higher the rate, and the more positively the response pattern is accelerated.
DISCUSSION

The immediate delivery of a response-contingent reinforcer appears to be necessary to the maintenance of a "scalloped" response pattern typically generated by FI schedules. Though median delay of reinforcement here was relatively short, 1 to 8 sec, it was sufficient to destroy the positively accelerated response pattern. The maximum delay was seldom taken, rather "extra" responses occurred and the delay was effectively shortened. In addition, delays of reinforcement typically lengthened the post-reinforcement pause whereas, when contingencies which closely approximated FI schedules were in effect (Conj 95%), the pause shortened.

Shull (1970, 1971) argues that there is no difference in mean post-reinforcement pause lengths between FI and Conj schedules with pigeons. Morgan (1970) has demonstrated transitional increases in median pause lengths in pigeons, when schedules changed from FI to Conj. He described the change as "unstable," however. In contrast, the present study demonstrates that the overall post-reinforcement pause distribution does in fact differ between FI and Conj schedules, despite only slight changes in mean pause lengths, at least in rats. The Conj schedule consistently generated longer post-reinforcement pauses. This suggests that the use of mean pause lengths as a descriptive measure of post-reinforcement pausing is not entirely accurate.
In addition, this research points out that the pause length is related to the response-reinforcement contingency. If a response produces the reinforcer with no delay, the post-reinforcement pause is shorter than when the delay is present. Lengthening the delay, increases the pause length; Powers and Edwards (1971) also support this point.

The temporal distribution of responses within an interval is also affected by eliminating the contiguity between a response and reinforcement. Powers (1968), Shull (1970, 1971) and Morgan (1970) have shown this effect using Conj schedules with a single response requirement. Whereas FI schedules generate positively accelerated response patterns, Conj schedules generate negatively accelerating rates. Shull (1970) described Conj schedule performance as characterized by "a pause after reinforcement, responding, and a second pause until reinforcement."

When reinforcement is independent of responding, both the response pattern and rate change (Skinner, 1948; Appel and Hiss, 1962; Herrnstein, 1966; Zeiler, 1968). Zeiler (1968) did not demonstrate large changes in responding on fixed time schedules of response independent reinforcement probably because on the average fewer than 10 sessions were given to response independent reinforcement before re-introducing the original contingencies. Powers and Edwards (1971) added a differential reinforcement of other behavior (DRO) contingency to FI schedules and observed response pattern changes when other-than-bar-pressing behavior was rein-
Thus, the positively accelerating response rates of FI schedules appear to be produced by the response-reinforcement contingency.

In attempting to account for the FI scallop, Dews (1962) posited the notion of a retroactive, rate enhancing, gradient of reinforcement. His position states that the maximal effect of reinforcement is exerted upon the response closest to reinforcement and the effect upon responding grows progressively weaker further back in the interval. Thus, although the response emitted immediately prior to reinforcement is strengthened, so too are responses emitted earlier. These responses are strengthened less, however, than those closer to reinforcement, due to the delay interval between their emission and the delivery of reinforcement. Thus, since the delay of reinforcement for a given response decreases as the interval elapses, the response rate increases.

The Dews (1962, 1970) hypothesis implies that short delays, e.g., less than 2 sec, would exert little or no effect on the FI pattern. Short delays would exert their effect on those few responses immediately preceding reinforcement. The larger portion of responses during the interval, indeed, most of the scallop itself, would not be affected by the very short delay. Thus, the short delay generated by the Conj schedule should not disrupt the scalloped pattern. The data from the present experiment do not demonstrate this effect; rather the short delays
exerted a massive effect in lengthening the pause, eliminating the scallop, and lowering the overall rate. Factors other than delay of reinforcement alone, therefore, appear necessary for the production of the FI scallop.

The behavior occurring at the instant of reinforcement appears to determine the response pattern generated by the schedule. In fixed interval schedules a response is required immediately before reinforcement; no delay of reinforcement is possible. When delays are introduced, other-than-bar-pressing-behaviors are likely to occur, and are likely to be reinforced. Thus, when longer delays are permitted, the probability that a bar press will occur decreases and, concommitantly, the likelihood of superstitious responding increases. Thus, since Conj schedules permit delays, they reinforce "other" behavior, and consequently generate lower rates. The actual length of the delay appears to determine the rate suppressing effect by limiting the amount of time during which other-than-bar-pressing can occur. The two or three second delay permitted competing responses to intervene and to be reinforced, thereby eliminating the scalloped pattern. Thus, it appears that the effect of reinforcement on the behavior occurring at the instant of reinforcement rather than the retroactive delay of reinforcement, per se, determines response patterns in FI schedules.
SELECTED BIBLIOGRAPHY


VITA

Daniel M. McCarthy

Master of Science

Thesis: Self-Imposed Delays of Reinforcement in Conjunctive Schedules

Major Field: Psychology

Biographical Information:

Personal Data: Born September 17, 1947 at Butte, Montana; Single.

Education: Ph.D. candidate, Utah State University; M. S. completed 1972, Utah State University, Logan, Utah, Psychology; B. A. completed 1969, Gonzaga University, Spokane, Washington, Psychology.

Professional Experience:

Laboratory Manager, 1969 to present. My duties as laboratory manager, Utah State University Psychology Animal Laboratory, were primarily administrative and supervisory. These duties include supervising the work of several part-time technicians, and coordinating ongoing faculty and graduate student research. A considerable portion of time is spent assembling and maintaining electromechanical support equipment.

Teaching and research assistant, 1969 to present with Dr. Carl D. Cheney, Utah State University, Department of Psychology.

I have taught an upper division course in Instrumentation. Currently I am a teaching assistant in an upper division Physiological Psychology course. My interests lie primarily in the Experimental Analysis of Behavior, behavioral pharmacology, and physiological psychology.

Affiliations: Member, American Association for the Advancement of Science; Member, Psi Chi (Secretary-treasurer, 1969-1970; President, 1970-1971).
Papers and Publications:


"Response rate and post-reinforcement pause relations in fixed interval and conjunctive schedules." Paper presented at the Sigma Xi Graduate Student Competition, Utah State University, Logan, Utah, 1972.