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by

Russell A. Powell

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Abstract

Several studies have shown that pigeons prefer variable over fixed schedules of reinforcement. The present research examined preference for variable versus fixed schedules of secondary reinforcement in humans. Experiment 1 used a concurrent-chains procedure allowing subjects to choose between mutually exclusive fixed-interval (FI) 30-sec and mixed-interval (MI) 30-sec alternatives. The effect of randomness in the MI schedule was also examined; the component intervals were presented in either the standard random order or in a nonrandom alternating order (an "AMI" 30-sec schedule). Experiment 2 used a similar procedure to directly compare preference for MI 30-sec versus AMI 30-sec alternatives. The results from these two experiments were inconsistent and contradictory. Experiment 3 used an entirely different procedure and presented subjects a single choice between fixed and variable alternatives with much larger time delays and reinforcement amounts, i.e., subjects could receive ten dollars at the end of one month (the fixed alternative), or they could gamble on receiving it immediately or in two months (the variable alternative). Nine out of ten subjects chose the variable alternative. These results are related to the ability of human subjects to respond in terms of large reinforcers presented at long delays.

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Table of Contents

Chapter Page

I. Introduction 1
II. Experiment 1 7
A. Method 8
Subjects 8
Apparatus and Setting 8
Procedure 9
B. Results and Discussion 12
Results 12
Discussion 15
III. Experiment 2 17
A. Method 18
Subjects 18
Apparatus and Setting 18
Procedure 18
B. Results and Discussion 20
Results 21
Discussion 22
IV. Experiment 3 25
A. Method 28
Subjects 28
Procedure 29
B. Results 30
C. Discussion 32
V. General Discussion 34

Tables 42
Figures 48
References 52
Appendix A: Literature Review 57
A. Preference Paradigms 57
B. Preference for VI versus FI 59
C. Preference for VR versus FR 69
D. Preference for Fixed versus Variable Delay 74
E. Substantive Issues 77
F. Conclusion 80
References 81
Appendix B: Questionnaires Used in Experiment 3 86

List of Tables

Table — Page

1 EXPERIMENT 1: Sequence of experimental conditions . 42

2 EXPERIMENT 1: Relative rate of responding in initial links, relative entries into terminal links, number of entries into each terminal link, and absolute response rates on initial and terminal link schedules 43

3 EXPERIMENT 2: Sequence of experimental conditions . 45

4 EXPERIMENT 2: Relative rate of responding in initial links, relative entries into terminal links, number of entries into each terminal link, and absolute response rates on initial and terminal link schedules 46

List of Figures

Figure	Page

1 The response panel used in Experiments 1 and 2 48
2 Diagram of procedure in Experiment 1 49
3 Relative rate of initial link responding to right alternative for each subject in Experiment 1 50
4 Relative rate of initial link responding to left alternative for each subject in Experiment 2 51

Introduction

Choice and preference are fundamental aspects of human behavior. Individuals characteristically distribute responses among many alternative sources of reinforcement. Alternatives may differ in the type and amount of reinforcement, as well as in the contingencies of reinforcement.

Preference for different types of contingencies may be an important factor in human behavior. For example, Emerson (1972) has proposed that humans prefer variable over fixed schedules of social reinforcement. Individuals who deliver social reinforcement on more variable schedules may thereby exert greater influence over the behavior of others. Thus, schedule preference may be a determinant in many social phenomena such as dominance, leadership, and charisma. This suggests that an individual's distribution of behavior may be altered by changing the operating contingencies in a choice situation. In summary, an analysis of schedule preferences in humans may have important implications for the prediction and control of human behavior. The present research investigated human preference for variable versus fixed schedules of reinforcement.

The most common paradigm used to measure schedule preference is the two-link concurrent-chains procedure (Autor, 1969). In the initial link, the subject responds on two concurrently available alternatives, usually programmed on equal variable-interval (VI) schedules. Meeting the requirement on an initial link alternative results in the presentation of a terminal link schedule of reinforcement. This is signalled by an exteroceptive stimulus change, while the other alternative becomes inoperative. Thus, in the initial link, the subject chooses between two mutually exclusive terminal link schedules. Preference between terminal link schedules is measured by relative rate of responding on the initial link schedules.

A second paradigm for measuring schedule preferences utilizes the switching procedure devised by Findley (1958). Responses on a change-over (CO) alternative change the schedule of reinforcement in effect on a second alternative. For example, in the procedure employed by Sherman and Thomas (1968), if the first response was on the CO alternative, the subject could not switch back to the original schedule. They were then committed to receiving reinforcement on the new schedule. Similarly, if the first response was on the presented schedule, the subject was committed to receiving reinforcement on that schedule. Thus, the first response was a choice response, and was similar to the initial link choice phase in the concurrent-chains procedure.

Both of these paradigms separate responding *for a schedule* from responding *on a schedule*. Response rates on a schedule are not good measures of preference for alternative contingencies of reinforcement since they may be heavily influenced by characteristics of the schedule itself. The concurrent-chains procedure has an additional advantage since it provides a measure of response rate on the initial links (in addition to CO responses). The Findley procedure may be considered similar to a chains procedure with FR initial link schedules.

The concurrent-chains procedure, with first link VI schedules, can be regarded as an extended version of a simple concurrent VI schedule. A well-known finding in the experimental analysis of choice behavior is that pigeons match relative rate of responding on two concurrently presented VI schedules to relative rate of reinforcement (Herrnstein, 1961). This effect, known as the matching law, has been replicated in a variety of situations and species (de Villiers, 1977), including humans (Pierce & Epling, 1983). Using the concurrent chains procedure, Herrnstein (1964a) found that pigeons matched relative rate of initial link responding to relative rate of terminal link reinforcement (when both terminal links consisted of VI and VD schedules).

In another experiment, Herrnstein (1964b) found that when one terminal link was a fixed interval (FI) schedule, pigeons responded for a VI alternative more than predicted by relative rates of reinforcement. More specifically, although the arithmetic means of each schedule were equal, e.g., VI 30 sec and FI 30 sec, pigeons strongly preferred the VI alternative. Subsequent research found that animals preferred variable over fixed schedules, whether the schedules were interval (Davison, 1969, 1972; Hursh & Fantino, 1973; Killeen, 1968; Navarick & Fantino, 1972, 1975), ratio (Fantino, 1967; Hendry, 1969; Navarick & Fantino, 1972, 1975; Rider, 1983b; Sherman & Thomas, 1968), or response independent delay of reinforcement (Cicerone, 1976; Rider, 1983a). With the exception of Sherman and Thomas who employed the Findley switching paradigm, these studies used the concurrent-chains procedure. Finally, in most of these experiments the variable alternative consisted of a "mixed" schedule: a type of variable schedule which controls for the number and size of component values in the schedule. For example, a mixed-interval (MI) 30-sec schedule might consist of an equal number of 15- and 45-sec intervals presented in random order.

Herrnstein (1964b) accounted for preference for the variable schedule by suggesting that a temporal scaling factor may be involved. In this account, the shorter component intervals in the VI schedule exert a disproportionate influence on responding, i.e., they are "weighted" more heavily. A number of studies have attempted to derive a transformation rule on this basis (Davison, 1969, 1972; Hursh & Fantino, 1972; Killeen, 1968), but results have been inconsistent. For example, Killeen suggests a harmonic transformation of the intervals, while

Davison's (1969) results are best described by a transformation of the reciprocals of the intervals to the third power. Frankel and Vom Saal (1976) conclude that "no consistent transformation has been found which is adequate to account for more than a limited set of data" (p. 71). Nevertheless, all suggested transformations weight shorter intervals more heavily, and the importance of this factor seems well-established.

In addition to the temporal scaling factor, Herrnstein (1964b) suggests his results are similar to gambling behavior in humans: "the gambler may be like the pigeons in the present experiment; they were 'placing their bets' consistently, if not wisely" (p. 181). In other words, preference for VI over FI results from the possibility of "winning" a shorter interval to reinforcement on the VI alternative. Thus, preference for VI may be largely a function of the random presentation of shorter intervals on VI, such that there is some probability of their occurrence whenever the VI schedule is selected. There have, however, been no studies that have directly manipulated this factor.

With respect to human preference for variable versus fixed schedules, research has been limited and inconclusive. Repp and Deitz (1975) used a switching procedure to examine preference for VR60 versus FR60 schedules of monetary reinforcement. The VR and FR schedules alternated automatically after each reinforcement, and a CO response was necessary to reinstate the previous schedule. All four subjects, age 10 to 12, switched to the VR schedule more often than to the FR schedule. Weiner (1966) used a similar procedure to examine preference in four adults for VR40 versus FR40 schedules of point delivery. However, Weiner found no preference for either schedule; the subjects rarely made a CO response, and simply responded on the two schedules as they were automatically presented in alternating order. In addition to using older subjects, the Weiner study differed from Repp and Deitz in other ways. Most notably, subjects were instructed to "get the highest score possible". Relative to this strategy, responding on the CO alternative would waste time and reduce total points earned.

There have been no human studies using the concurrent-chains procedure. Significantly, this is the most commonly used procedure in animal research where results have been fairly consistent. Furthermore, as previously noted, human responding on concurrent VI schedules has been shown to be similar to that found in animals (Pierce & Epling, 1983). Given that the concurrent-chains procedure is an extended version of a simple concurrent, it may be that schedule preferences in humans would more closely match the results obtained with animals if this procedure was used. The present research examined preference in adult humans for variable versus fixed schedules of monetary reinforcement using a concurrent-chains procedure. It was predicted that relative rate of responding in the initial links would be greater for the alternative leading to the variable schedule. The role of "gambling" in determining variable schedule preference was also examined by manipulating the randomness of the variable schedule. It was predicted that the variable schedule would be more preferred when the schedule components were presented in random, rather than nonrandom, order.

Experiment 1

Experiment 1 used a concurrent-chains procedure to examine preference in humans for variable versus fixed schedules of monetary reinforcement. The variable alternative consisted of an MI 30-sec schedule with component intervals of 5 and 55 seconds. The fixed alternative was an FI 30-sec schedule. It was hypothesized that relative rate of responding would be greater on the initial link alternative leading to the MI schedule. Experiment 1 also examined the "gambling" effect in determining preference for the variable schedule. Across conditions, two types of MI schedules were employed: a standard MI schedule with 5 and 55 second components presented in random order, and an "alternating mixed interval" (AMI) schedule with the two components presented in alternating order. If the "gambling" effect is important then subjects should exhibit greater preference for MI over FI than for AMI over FI. This result would indicate that the random presentation of component intervals is a determinant of human preference for variable schedules.

Method

Subjects

Four experimentally naive female university students served as subjects. They had answered a poster announcing payment for research participation, and were selected mainly on the basis of an expressed need for money. Each subject signed a contract stating that remuneration would be based on points earned during the experiment, plus a ten dollar bonus for completion of all scheduled sessions.

Apparatus and Setting

Subjects responded on the panel displayed in Figure 1. Response buttons, which could be illuminated, were 1.5 cm square and required a force of 500 grams. The initial link buttons were both white, while left and right terminal link buttons were blue and yellow, respectively. Consumatory response buttons were colored to match the terminal link buttons, and were included to increase sensitivity to contingencies (Matthews, Shimoff, Catania, & Sagvolden, 1977). Left and right counters registered total points earned on respective terminal link schedules. For each pair of buttons/counters, the left-side alternative was labelled "A", and the right-side alternative was labelled "B".

Subjects sat facing the response panel that was positioned on top of a desk. Since pilot subjects complained of boredom, a radio provided music during experimental sessions. Colbourne programming equipment located in a separate room controlled presentation of events and recorded subjects' responses.

Procedure

Prior to the first session, subjects were asked to read the following list of instructions:

"1. Do not press any buttons until you hear the beep which signals the start of the experiment.
2. In this study you earn points by pressing the various buttons. Press the buttons *only when they are lit*. When 2 buttons are lit simultaneously, you can press whichever one of them you choose.
3. Each time you earn a point, it is recorded on one of the counters on the panel. Each point you earn is worth *8 cents* and your task is to earn as much as possible.
4. Both the start and the end of the session are indicated by the sound of the beeper. When the beeper sounds to end the session, please wait in your chair until the researcher arrives.

5. If you have any questions about the procedure, please reread these instructions."

Concurrent-chain schedules, outlined in Figure 2, were the operative contingencies. During the choice phase, two white initial link buttons were illuminated and independent VI schedules were operative on each button. A change-over-delay (COD) was also in effect during this phase. The COD stipulated that a delay of *n* seconds would occur following a change-over from one button to the other. Responses during the delay were not effective in meeting the VI schedule requirements. When the subject completed the requirement on either initial link, both buttons turned dark and one of the terminal links became operative. Meeting the VI requirement on the left initial link button resulted in the illumination of the left (blue) terminal link button, while meeting the VI requirement on the right initial link button resulted in the illumination of the right (yellow) terminal link button. Completing the schedule requirement on either terminal link resulted in that button going dark and the illumination of its associated consumatory response button. A single response on this button then turned it dark and registered a point on the appropriate counter. The two initial link buttons were then illuminated to initiate another choice phase.

The initial links consisted of VI 10-sec schedules. While research with pigeons has typically used VI 60-sec schedules (e.g., Davison, 1969), pilot subjects for the present study were consistently insensitive to terminal link schedules when initial links were this long. Terminal link alternatives constituted the independent variable; the left-side terminal link was always an FI schedule, while the right-side terminal link consisted of either an FI, MI, or AMI schedule. The AMI 30-sec schedule consisted of 5 and 55 second intervals presented in alternating order. The MI 30-sec schedule consisted of an equal number of 5 and 55 second intervals presented in random order, with the restriction that there could not be more than four consecutive presentations of the same interval value. Dependent measures consisted of relative rates of responding on initial link schedules, absolute rates of responding on initial and terminal link schedules, and total and relative number of entries into each terminal link.

The sequence of experimental conditions for each subject is presented in Table 1. A modified ABCB reversal design was used, counterbalanced across subjects. Subjects A3 and A4 also received Condition D comparing preference for FI 30-sec versus FI 15-sec schedules. This was because, during early sessions, these subjects developed a stereotyped response pattern of switching back and forth between alternatives. Condition D was initiated to determine if these subjects were at least sensitive to different terminal link pay-offs, as would be indicated by preference for the richer schedule. The stereotyped switching pattern was also the reason for the longer COD used with Subject A4; it was increased first to four seconds to try and prevent the occurrence of the stereotyped pattern that Subject A3 had previously demonstrated. When the pattern developed anyway, the COD was increased to 15 seconds in session 12 to try and eliminate it. With a 15 second COD, switching back and forth would reduce overall earnings, and continued switching would strongly indicate that choice was not under control of monetary reinforcement.

Subjects were given three sessions per day. Sessions lasted 50 minutes with 10 minute breaks between sessions. All subjects initially contracted to participate for four consecutive days, and Subject A3 agreed to return for a fifth day. At the end of the final session for the day, total points registered were recorded, and the subject was informed of monetary earnings. On average, subjects earned $6.00 per session.

Results and Discussion

Results

Results for each session are based on data from the entire session. Preference for terminal link schedules was determined by relative rate of response on the initial link alternatives. The number of responses on one alternative was divided by the total number of responses on both alternatives. Similarly, relative entries into terminal links consists of number of entries into one terminal link divided by total number of entries into both terminal links.

Relative rates of response in the initial link are displayed in Figure 3. The first three sessions constituted a baseline condition with FI 30-sec schedules presented in both terminal links. During this condition, relative rates were close to .5 for all subjects. This means that subjects were responding equally on both alternatives, suggesting an absence of position bias.

Two subjects demonstrated schedule preferences. Subject A2 strongly preferred MI over FI, with exclusive responding for the MI alternative during sessions 8 and 9. On the other hand, she showed no preference for AMI over FI. In fact, during session 6, relative response rate for the initial link alternative leading to AMI was .33, indicating greater responding for the FI alternative. Subject A1 also preferred MI over FI, and not AMI over FI. However, the effect was weak. While preference for MI increased steadily during the first presentation of Condition B (sessions 4 to 6), it was less consistent during the second presentation of that condition (sessions 10 to 12). Relative responding for MI decreased from .56 in session 10 to .49 in session 11, before finally recovering to .63 in session 12. It should be noted that, with both subjects, conditions were sometimes changed before preferences had stabilized. Unfortunately, stability could not be used as a criterion for changing conditions because of the limited number of sessions subjects participated in. This was also the case in Experiment 2.

Relative response rates for Subjects A3 and A4 indicate no consistent schedule preferences in any of the conditions presented to them. Rates deviated little from .5 in all sessions, especially for Subject A4. Informal observation revealed that both subjects had a consistent pattern of switching back and forth between alternatives; they would respond on the left side alternatives, earn a point, then respond on the right side alternatives, earn a point, then back to the left side, etc. This pattern was maintained even with FI 15-sec versus FI 30-sec alternatives during final sessions, and, for Subject A4, when the COD was increased to 15 seconds in session 12.

Additional results are presented in Table 2. For most subjects, relative entries into terminal links parallel relative rates of responding in the initial links. That is, a higher proportion of responses to an initial link alternative usually resulted in more frequent selection of the associated terminal link schedule. The significant drop in total number of terminal link entries by Subject A4 in session 12 is the result of the 15 second COD operative during this session. The subject continued to switch back and forth between alternatives despite the long COD, and thus spent more time in the initial links.

With respect to absolute response rates, terminal link rates by Subject A1 were consistently higher on MI and AMI than on FI, and usually higher on MI than on AMI. However, absolute rates by Subjects A2, A3, and A4 did not differ between terminal link schedules. There were also between subject differences in absolute response rates; rates were very low for Subject A2, especially on terminal link schedules, and extremely high for Subject A4. Informal observation indicated that Subject A4 generally responded at a high rate throughout the reinforcement interval, while Subject A2 usually waited a period of time before responding. Interestingly, Lowe (1979) notes that human FI performance is characterized by two main patterns: a low rate pattern consisting of a few responses emitted at the end of the interval, similar to Subject A2's behavior, and a high rate pattern consisting of a high undifferentiated rate throughout the interval, similar to Subject A4's behavior.

Discussion

Only two subjects behaved in accordance with the predictions. Subject A2 developed strong preference for MI over FI, and showed no preference for AMI over FI. Subject A1 showed a similar pattern, though preference for MI was inconsistent during the second presentation of the MI versus FI condition. It is difficult to account for this inconsistency, though it may due to an interaction with the preceding AMI versus FI condition. The results in general suggest that preference for variable over fixed schedules may not be as prevalent a phenomenon in humans as it is in animals. When such preference occurs, however, the random presentation of component intervals does seem to be a determining factor.

Subjects A3 and A4 showed no preference for any of the schedule alternatives presented to them. This occurred despite the use of relatively short initial link schedules, which should have enhanced differential preference for terminal link alternatives (Hursh & Fantino, 1974; Frankel & Vom Saal, 1976). Their stereotyped patterns of switching back and forth between alternatives were extremely persistent and insensitive to changing contingencies. This is indicated by maintainance of the patterns even when terminal link alternatives provided different rates of reinforcement, i.e., FI 15-sec versus FI 30-sec alternatives, and when an extremely long COD was instituted with Subject A4. In the latter case, switching greatly increased the relative time spent in the initial links and significantly reduced overall earnings for the session. This suggests that, at least in later sessions, initial link responding was not under functional control of terminal link alternatives.

Experiment 2

Experiment 1 indirectly compared MI and AMI schedules by assessing preference for each in comparison to an FI schedule. Two subjects preferred MI over FI, but not AMI over FI. Subject A1 showed a transient preference for MI over FI, but no preference for AMI over FI. This indicates that preference for MI over FI is at least partially a function of the random presentation of component intervals in the MI alternative. It also suggests that MI should be preferred over AMI in a direct comparison of the two schedules, i.e., if MI is preferred over FI and AMI is not preferred over FI, then by transitivity MI should be preferred over AMI.

Experiment 2 measured preference for MI 30-sec versus AMI 30 sec schedules of monetary reinforcement. These schedules were presented in the terminal links of a concurrent chains procedure similar to that used in Experiment 1. Because the two alternatives differed only in the degree of randomness with which the component intervals were presented, the present experiment provided a strong test for the importance of this factor in determining preference for MI. On the basis of the results obtained in Experiment 1, it was predicted that subjects would be more likely to prefer the MI schedule of reinforcement.

Method

Subjects

Four female undergraduates served as subjects. They were selected in the same manner as the subjects in Experiment 1, and made the same contractual agreements for participation.

Apparatus and Setting

The apparatus was identical to that used in Experiment 1. The programming was changed to allow the scheduling of either FR1 or VI 10-sec initial link schedules.

Procedure

The concurrent-chains procedure was identical to that used in Experiment 1. The sequence of experimental conditions for each subject is outlined in Table 3. In condition A, subjects were presented terminal link schedules of MI 30 sec and AMI 30-sec. If the subject showed no schedule preference, condition A2 was instituted in which the initial link schedules were reduced from VI 10-sec to FR1. Research has shown that FR1 initial link alternatives greatly increase the probability of schedule preference occurring (Frankel & Vom Saal, 1976). If subjects remained indifferent despite this manipulation, their further participation in the experiment was terminated.

Subjects B3 and B4 showed some preference in early sessions, and so were presented a more complete set of conditions. Subject B3 was presented an ABA reversal design, where B represented a baseline condition with AMI schedules presented in both terminal links. However, because there was no demonstration of preference during the second presentation of condition A, initial links were then reduced to FR1 to see if preference could be obtained.

An entirely different procedure was used with Subject B4. In place of a baseline condition, the position of the terminal link MI and AMI schedules were simply reversed across blocks of sessions. The subject's responding would then "track" a preferred alternative as its position, left or right, changed. This procedure therefore allowed for more sessions in which preference could be demonstrated: an important advantage given the difficulty of obtaining preference with previous subjects and given the limited number of sessions in which subjects participated. Because Subject B4 developed a consistent preference over the first nine sessions, conditions C and D were then instituted. These conditions tested whether, by transitivity, the same preference pattern would occur when the MI and AMI alternatives were each compared to an FI alternative. These final conditions were thus identical to the comparisons made in Experiment I.

Results and Discussion

Results

Results are reported in the same manner as in Experiment 1, and are based on data from entire sessions. Preference for terminal link schedules was measured as relative rate of responding on initial link alternatives.

Relative rates of responding on initial link alternatives for each subject are presented in Figure 4. Subjects B1 and B2 showed no preference for either the MI or AMI schedules; relative response rates remained close to .5 in all sessions. Since this pattern occurred even when initial link schedules were reduced to FR1, participation by both subjects was terminated following their sixth session.

Schedule preferences were shown by two subjects. Subject B3 seemed to preferred MI over AMI in the first 3 sessions, especially in session 3 when 70% of initial link responding was on the alternative leading to the MI schedule. In subsequent conditions, however, relative responding for the left alternative remained only slightly above .5. This seems to be a position bias since it also occurred during the baseline condition in sessions 4 to 6. When initial link alternatives were then reduced to FR1 in sessions 10 to 12, a strong preference for AMI over MI developed. Similar results were obtained with Subject B4. While in sessions 2 and 3, there seemed to be some preference for MI over AMI, in subsequent sessions there was strong preference for the AMI alternative. Greater preference for AMI was also demonstrated in the comparisons involving the FI alternative; the subject preferred AMI over FI more so than MI over FI. In the latter condition, exclusive preference for MI in session 11 reverted to strong preference for FI in session 12. On the other hand, preference for AMI over FI was consistently strong across all sessions of that condition (sessions 13 to 15).

Additional results are reported in Table 4. As in Experiment 1, relative entries into terminal link alternatives generally parallel relative rates of initial link responding. When initial link alternatives are reduced to FR1, they are of course exactly equal. With respect to absolute response rates (not reported for FR1 initial link schedules), between subject differences are apparent. As in Experiment 1, two extremes were noted which are similar to two main patterns found in human FI performance (Lowe, 1979). Extremely high response rates were emitted by Subject B1; extremely low terminal link response rates were emitted by Subjects B3 and B4, with responses often emitted only at the end of the scheduled interval. Significantly, these low rate patterns developed concurrently with the development of subjects' preference for the AMI alternative. However, there were no significant differences in terminal link response rates as a function of the type of schedule in operation.

Discussion

Experiment 2 measured preference for MI versus AMI schedules of monetary reinforcement presented in the terminal links of a concurrent-chains procedure. On the basis of results obtained in Experiment 1, it was hypothesized that subjects would be more likely to prefer the MI schedule alternative. This would demonstrate that the random presentation of component intervals in the variable alternative facilitates preference for that alternative.

The present results do not support the hypothesis, and contradict findings obtained in the previous experiment. In Experiment 1, where MI and AMI schedules were each compared to an FI schedule, two subjects showed greater preference for MI than for AMI. In the present experiment, with MI and AMI directly compared, two subjects preferred AMI more than MI. Subject B3 showed this preference only when the initial link schedules were reduced to FR1. Unfortunately, the effect was obtained on the last day of sessions, and the subject was unable to return for further testing. However, Subject B4 demonstrated the effect both when MI and AMI were compared to each other and when each was compared to an FI alternative. Thus, the stronger preference for AMI was transitive across the various types of comparisons.

Similar to Experiment 1, two subjects in the present experiment demonstrated no consistent schedule preferences.

This pattern was maintained even when the initial links were reduced to FR1. One of these subjects, Subject B1, emitted extremely high response rates similar to that observed in Subject A4 in Experiment 1, who also showed no schedule preference. This suggests that inappropriate high rate patterns on interval schedules may be related to a general insensitivity to experimental contingencies and subsequent lack of differential responding to alternatives. Such insensitivity was certainly the case with Subject A4, as previously noted.

While high rate patterns are associated with lack of schedule preference, low rate patterns of terminal link responding seem to be consistently associated with the occurrence of schedule preference. In both experiments, the strongest preferences were shown by subjects who emitted such patterns. However, while a low rate pattern was associated with preference for MI by Subject A1 in Experiment 1, it was associated with preference for AMI by two subjects in the present experiment. Both Subjects B3 and B4 developed low terminal link response rates concomitant with increasing preference for the AMI schedule.

Interestingly, Subject B4 commented, following her debriefing, that her preference for AMI was motivated by an attempt to reduce the effort involved in obtaining reinforcement. She stated that the AMI schedule allowed her to know when to respond. During the long component, she would count out the interval before responding, while during the short component there was no need to count since reinforcement was relatively immediate. Thus, she only had to count on every second occasion when AMI was selected. By contrast, the MI schedule always required immediate responding, in case the short interval was upcoming, and the FI schedule always required counting each time the schedule was selected. Thus, in terms of reducing both overt and covert response cost, the AMI alternative was most efficient. However, this explanation implies that terminal link response rates should have been consistently lower on AMI than on MI. In fact, this was not the case; absolute rates were equally low on both schedules, indicating that reduction of overt response cost was not really a factor in determining preference. Reduction of covert response cost does remain a possible factor, but unfortunately there is no means of independently assessing the subject's covert behavior during schedule performance.

Thus, while Experiment 1 indicates that randomness may be a contributing factor in determining preference for variable over fixed schedules of reinforcement, Experiment 2 indicates that the opposite may also be true. In some cases, humans may actually demonstrate decreased preference for MI as a function of its randomness. Reduction in response cost may be one explanation for this effect, but why the present results are opposite to those obtained in

Experiment 1 is difficult to account for. Experiments 1 and 2 differed significantly in terms of the type and order of conditions presented to subjects, and this may have had an effect. The inconsistent results may also be a function of uncontrolled for between-subject differences; for example, subjects who have a history of reinforcement for gambling (i.e., winning) may prefer the random alternative, while subjects who have a history of punishment for gambling (i.e., losing) may prefer the nonrandom or fixed alternative. Further research is required to determine the exact conditions under which one effect is obtained versus the other. Experiment 3, however, examines the more basic question as to why preference for variable over fixed schedules is so difficult to obtain in humans, while it has been such a consistent finding in animal research.

Experiment 3

Results of Experiments 1 and 2 appear variable and contradictory. Most surprising is the general lack of preference for variable over fixed schedules of reinforcement, although such preference has been a consistent finding in earlier studies with animals. One possible explanation for the difference is that, on the schedules presented, the human subjects did not weight the interreinforcement intervals in the same manner as would animals. More specifically, humans may be less effected by the shorter interval to reinforcement on the variable alternative, and may be more inclined to respond in terms of the overall rate, rather than the local rate, of reinforcement. Thus, given variable and fixed schedules of equal mean length, humans may tend to respond equally to both alternatives. If a preference were to be demonstrated, it would then be on the basis of some factor other than the local rate of reinforcement, for example, reduction of response cost.

The above analysis is supported by some informal observations made during Experiments 1 and 2. Following a session, subjects would sometimes remark how boring the session was, yet show considerable interest in what their total earnings were for the session. This suggests that total reinforcement for the session may have been the more potent consequence maintaining behavior during the session. That subjects were specifically instructed to "earn as much as possible" may have contributed to this tendency. A second point is that, during informal questioning following their participation in the experiment, some subjects stated that they were well aware that the schedule alternatives presented to them were generally equal in terms of overall pay-off value. This includes all subjects who were consistently indifferent between the alternatives presented to them. It also includes Subject B4, who claimed that her preference for AMI was a function of trying to reduce response cost, as well as Subject A2, who stated that she strongly preferred MI over FI simply because it was more interesting. Thus, these verbal reports indicate that most subjects readily equated the average payoffs associated with the schedules presented to them, and, in accordance with this discrimination, most of these subjects then responded equally to both alternatives.

Herrnstein (1981) has proposed a self-control model which is relevant to the present discussion. The model states that response strength for delayed reinforcement may be effected by a number of factors, including type of reinforcement, level of deprivation, and inherent differences between species. Thus, interval values which effect responding for primary reinforcement in deprived pigeons would not necessarily be effective with respect to human responding for secondary reinforcement. In other words, while pigeons may show strong preference for receiving food in 5 seconds on the short interval of an MI schedule versus waiting 30 seconds on an FI schedule, humans may regard such a temporal difference as relatively trivial, especially when each reinforcement consists of a relatively minute amount (e.g., a single point worth only 8 cents, as in the preceding experiments). Of more relevance for humans might be the larger, more delayed reinforcement of maximizing one's total earnings for the session. This would then account for the general pattern of equal responding between alternatives as shown by many subjects in the preceding experiments. It also suggests that the use of large reinforcers presented at long delays may be an appropriate procedure for studying certain aspects of choice behavior in humans.

Experiment 3 was designed as a demonstration of possible factors governing schedule preferences in humans. Subjects chose between alternative methods of payment which were roughly analogous to the MI and FI alternatives used in the preceding experiments, only using much larger time delays and reinforcement amounts. Subjects made a single choice between two methods of payment: the "fixed" alternative consisted of receiving ten dollars at the end of one month, while the "variable" alternative consisted of a gamble between receiving the ten dollars immediately and receiving it at the end of two months. It was expected that choice between these alternatives would be a highly relevant task for humans, and it was predicted that the variable alternative would now be strongly preferred.

Method

Subjects

Ten female university students served as subjects. They were selected in the same manner as subjects were in the previous experiments.

Procedure

The researcher met with each subject individually. The subject was informed that the study required them to answer a couple of questionnaires for which she would be paid ten dollars. She was also informed that she may not receive the money immediately. The subject was asked if she was agreeable to this condition, and all subjects consented. The researcher next stated that no questions would be answered while the questionnaires were being filled out. The subject was then handed the first questionnaire, and was left alone. After approximately three minutes, the researcher returned, collected the first questionnaire, and handed the subject the second questionnaire. The subject was then left alone for approximately five minutes. Following this, the subject was paid the ten dollars, regardless of her choice on the first questionnaire. She was then debriefed.

The questionnaires are presented in Appendix B. On the first questionnaire, the subject was informed that part of the study involved determining "*when*" she would receive the ten dollars. The subject was asked to choose between two alternatives:

1. Alternative A: The money would be received in one month's time.
2. Alternative B: The money would be received either that day or in two months' time - to be

determined by a coin flip.

In this manner, alternative B provided a 50% chance of receiving the money that same day versus receiving it in two months. With alternative A, however, it was a certainty that the subject would have to wait one month for payment.

On the second questionnaire, the subject was asked to indicate her preference for: (1) receiving the ten dollars now versus in one month, (2) receiving it in one month versus in two months, and (3) receiving it now versus in two months. Strength of preference was also assessed using seven point rating scales. In addition, the subject was asked to write a short paragraph on her reasons for choosing the method of payment that she did.

Results

On the first questionnaire, nine out of 10 subjects chose Alternative B, i.e., to gamble on receiving the 10 dollars now versus in two months. This result is highly significant, $Z = +2.53$, $p < .02$. Interestingly, the subject who chose not to gamble, Subject C4, indicated in her written response on the second questionnaire that she did not need the ten dollars at that moment, but would need it for a special event in one month.

For those subjects who chose Alternative B, responses to the second questionnaire were analyzed for significant effects. On each of the three questions, all nine subjects indicated that they preferred to receive the money at the earlier period of time, e.g., now rather than in one month. On the strength of preference ratings, between question differences were found to be highly significant, $F(2,16) = 7.44$, $p < .01$. Further analysis, using Scheffe's Multiple Range Test, revealed significant differences between ratings on question 1 (Mean rating = 5.44) and question 2 (Mean = 3.44), and between question 2 and question 3 (Mean = 5.89). In other words, subjects reported significantly stronger preference for receiving the money now rather than in either one or two months, than for receiving the money in one month rather than in two months. On the other hand, subjects reported that preference for receiving the money now rather than in two months was only slightly stronger than for receiving it now rather than in one month. In summary, the ratings indicate that receiving the money now rather than in one or two months is highly preferred, but that receiving it in one month rather than two months is only slightly preferred.

The second questionnaire also required subjects to write a few sentences explaining why they selected the alternative they did on the first questionnaire. Verbal reports from seven out of the nine subjects [illegible] difference in [illegible].

ject [illegible]

[illegible]

> don't think that waiting two months would kill me. However, the chance of receiving it today is more appealing."

The report indicates that there is little difference between receiving payment in one month rather than in two months, while the possibility of immediate payment is highly valued. It is also worth noting that three of these subjects mentioned, as an additional reason, that they simply preferred the "gamble". For example, Subject C10 wrote that part of the reason for her choice was "because it's a bit of a gamble and so more fun, not just cut and dried". In other words, the gamble itself was reinforcing which contributed to the attractiveness of Alternative B.

Discussion

The results for Experiment 3 strongly support the hypothesis: nine out of ten subjects preferred the variable alternative. The one subject who chose the fixed alternative later stated that she did not need the money at present but would need it in one month. In behavioral terms, this might be referred to as a relative lack of 'deprivation' for the intended reinforcer. As such, her behavior does not contradict the hypothesis which assumes that subjects have a present requirement for the money. Her behavior instead seems to represent a form of "banking" in order to avoid a future state of requirement.

The subjects' ratings indicate that their selection of the variable alternative was a function of a strong preference for receiving the money immediately versus later. This matches Herrnstein's (1964b) notion that preference for variable over fixed schedules is due to a heavier weighting of the shorter interval to reinforcement. Written statements generally parallelled the rating patterns, although three subjects indicated that reinforcement associated with the act of gambling was also involved.

The variable results of the previous experiments contrast with the rather consistent results found in the present experiment. Presumably, this is because the present experiment used interval and reinforcement values highly relevant for humans. This indirectly supports the notion that the behavior of some subjects in the preceding experiments was not being governed by the local rate of reinforcement available on each particular presentation of a schedule; rather, total reinforcement for the session may have been the more relevant consequence. The present results also suggest that, in order to obtain results similar to those found in pigeons or rats, one may have to use parameters which are in some ways more suitable for humans.

However, it should be noted that the present experiment differed from the previous two experiments in a variety of ways. In addition to much larger interval and reinforcement values, subjects' choices were based on verbal instructions as opposed to actual exposure to the contingencies. The processes governing behavior under verbal instructions are not well understood at present, and it is recognized that such behavior may differ from contingency shaped behavior (e.g., Catania, Matthews, & Shimoff, 1982). In addition, the present experiment allowed only a single choice, while preference in the previous experiments was measured on the basis of multiple choices. As a result, the present study is by no means definitive; it is simply suggestive as to some of the variables operative in the previous two experiments. Nevertheless, it also stands as an interesting finding on its own, and is worthy of further investigation.

General Discussion

The major purpose of this thesis was to investigate whether humans would prefer variable over fixed schedules of monetary reinforcement. Such preference has been previously demonstrated in pigeons responding for MI versus FI schedules of primary reinforcement (e.g., Davison, 1969). The first two experiments used a concurrent-chains procedure similar to that used in the pigeon research, and obtained mixed results. Experiment 3 used analogues of variable and fixed schedules, with much larger time and reinforcement values, and obtained relatively consistent preference for the variable alternative. The results suggest that preferences in humans may be similar to those found in pigeons, but the parameters used must be relevant to the species being investigated.

In the preceding discussion, results were interpreted in terms of a strong tendency by humans to respond on the basis of overall reinforcement for the session. Also of relevance is the distinction between *within-meal* and *between-meal* behavior as suggested by Collier, Hirsch, and Kanarek (1977). They propose that the typical operant paradigm, with its emphasis on discrete responses and piece-meal reinforcement, is similar to the behavior of an organism during a meal. The organism's response results in relatively immediate reinforcement, which in turn is relatively small. As Collier et. al. point out, such within-meal behavior must be distinguished from between-meal behavior. In attempting to obtain the next meal (as opposed to the next bite), the organism may face much longer delays to reinforcement, which in turn consists of the entire meal. Thus, investigations of within-meal behavior may not be useful in understanding the between-meal behavior of an organism. The results of the present thesis suggest that this problem may be particularly important in operant studies of human behavior. The "within-meal" paradigm of the first two experiments yielded highly variable results; the "between-meal" paradigm of the last experiment yielded relatively consistent results. Thus, humans' ability to respond for over-all reinforcement in a session may mean that the between-meal paradigm is a more appropiate paradigm for studying certain aspects of human operant behavior.

Also of relevance to the present study is research by Kahneman and Tversky (1979) on risk-taking behavior in humans. They found that most humans tend to be "risk-averse" when choosing between risky versus non-risky options for monetary gain. For example, if given a choice between a 100% chance of receiving 10 dollars and a 50% chance of receiving 20 dollars versus nothing, most subjects select the former nonrisky alternative. Both alternatives are, however, equivalent in that, if each were presented a number of times, the average pay-off (or "expected value") associated with each would be the same, i.e., 10 dollars. Preference for the risky alternative is presumed to be a function of the relative gain in value associated with each alternative. More specifically, the gain in value associated with an initial increment of 10 dollars is construed as greater than the gain in value associated with any additional increment of 10 dollars. Using Herrnstein's (1964b) terminology, the gain in value associated with going from zero to 10 dollars is "weighted more heavily" than than the gain in value associated with going from 10 to 20 dollars. Thus, receiving 10 dollars on the nonrisky alternative outweighs the 50% chance of receiving an extra 10 dollars on the risky alternative. The risky alternative would have to be either substantially larger in amount and/or more probable in order to be preferred.

There is a direct parallel between the Kahneman and Tversky (1979) paradigm and the delay of reward precedure used in Experiment 3. In the former paradigm, the alternatives differ in the amount and probability of reinforcement; in the delay procedure, the alternatives differ in the size and probability of the interval to reinforcement. Thus, preference for the variable alternative may be interpreted as an instance of risk-taking behavior with respect to the temporal delay of reinforcement. However, while a heavier weighting of an initial increase in amount results in risk-averse behavior in the Kahneman and Tversky paradigm, a heavier weighting of the shorter interval to reinforcement results in risk-seeking behavior in the present procedure. The principles are similar, but the results are opposite.

A secondary purpose of the present thesis was to investigate the effect of random presentation of component intervals on preference for the variable schedule. The hypothesis in Experiments 1 and 2 was that the random presentation of intervals should enhance preference for MI over FI. This hypothesis was supported by the one subject who clearly preferred MI over FI; she showed no preference for AMI over FI. Unfortunately, most subjects showed no preference for MI over FI, and some subjects even preferred the nonrandom AMI alternative over the MI alternative. Another problem is that some of the possible processes that determined schedule preferences in these experiments may be relevant only to human behavior. For example, following her debriefing, Subject A2 reported that she strongly preferred MI over FI, not because it paid better, but because it was simply more "interesting". This suggests that her preference for MI may have been at least partially a function of secondary reinforcement associated with the "act of gambling". Thus, the results from these studies may not be that applicable to previous findings in pigeons, who are presumably responding simply to obtain the scheduled reinforcer.

While random presentation of intervals was not manipulated in Experiment 3, the results do provide evidence on the importance of this factor. Subjects' responses to the second questionnaire indicated that, with the exception of the "banking" behavior exhibited by one subject, they consistently preferred the alternative providing the shorter interval to reinforcement. In addition, the written responses by many subjects indicated that they selected the gamble primarily because of the possibility of receiving the money immediately. All of this would suggest that the random occurrence of the shorter interval to reinforcement associated with the variable alternative was a determining factor for the preferences exhibited. However, it must be noted that these measures are only verbal statements of preference. While verbal preference may be suggestive of behavioral preference under actual choice conditions, the two measures may sometimes yield discrepant results. For example, Morgan and Lindsley (1966) found that, in two out of four subjects, verbal preference for monophonic versus stereophonic music did not match actual choice behavior.

A different point concerns the insensitivity to contingencies shown by some subjects in the first two experiments. In particular, two subjects in Experiment 1 developed stereotyped response patterns which were extremely insensitive to procedural changes which should have eliminated such behavior. A post-experiment report by one of these subjects, Subject A4, suggests that this behavior was maintained by the formation of a "self-rule" during earlier phases of the experiment. More specifically, she stated that, during early sessions, she found that switching back and forth between alternatives was the best way to maximize over-all earnings. In subsequent sessions, she was so intent on following this strategy that she did not notice changes in contingencies which made this strategy inappropriate. In addition, she believed that points were contingent on number of button presses, i.e., that ratio contingencies were in effect. This report is congruent with her extremely high "ratio-like" response rate.

Lowe (1979) has suggested that the formation of self-rules, such as the above, may be typical of human subjects. On the other hand, Weiner (1983) emphasizes that self-rules should not be used as post-hoc causal explanations for behavior; rather, it is necessary to examine the past and present contingencies of which the subject's present verbal behavior may be a by-product. Subject A4's statement indicates that her self-rules arose, at least partially, as a function of her own interaction with the contingencies in earlier phases of the experiment. However, Lowe suggests that self-rules may also arise from such factors as pre-experimental history (uncontrolled for in the present experiments), and from instructions provided by the experimenter.

The instructional effect is of particular relevance to the present study. The instructions used in Experiments 1 and 2 emphasized only the response, i.e., button pushing. In a review of the literature on human operant conditioning, Baron and Galizio (1983) conclude that "instructions about the response readily initiate responding but also produce tendencies to respond regardless of the schedule" (p. 500). This suggests that the insensitivity to contingencies exhibited by some subjects in the present study may have been to some extent a function of the instructions used. Thus, self-rules which may have served to maintain those behavior patterns can be conceptualized as possible by-products of those instructions.

Interestingly, Baron and Galizio (1983) note that instructions which accurately describe the contingencies, as opposed to the response, tend to produce response patterns appropriate to the schedule of reinforcement in effect. In addition, Matthews, Shimoff, Catania, and Sagvolden (1977) found that keeping instructions to a minimum and shaping the response will also produce greater sensitivity to contingencies. Thus, if the present study had used instructions describing the contingencies, or if responding had been shaped, fewer inappropriate schedule performances may have occurred. In turn, this may have eliminated some of the inconsistent results, and allowed for a more powerful test of the hypotheses. Further research is required to investigate this possibility.

Table 1

Experiment 1: Sequence of experimental conditions

Subject No.	Condition	Number of Sessions	C.O.D. (in sec.)	Initial Link Schedule (in sec.)	Terminal Link Schedule (in sec.) Left	Right
A1	A	3	1	VI-10	FI-30	FI-30
	B	"	"	"	"	MI-30
	C	"	"	"	"	AMI-30
	B	"	"	"	"	MI-30
A2	A	3	1	VI-10	FI-30	FI-30
	C	"	"	"	"	AMI-30
	B	"	"	"	"	MI-30
	C	"	"	"	"	AMI-30
A3	A	3	1	VI-10	FI-30	FI-30
	B	"	"	"	"	MI-30
	C	"	"	"	"	AMI-30
	B	"	"	"	"	MI-30
	D	"	"	"	"	FI-15
A4	A	3	4	VI-10	FI-30	FI-30
	C	"	"	"	"	AMI-30
	B	"	"	"	"	MI-30
	C	1	"	"	"	AMI-30
	D1	1	"	"	"	FI-15
	D2	1	15	"	"	FI-15

Table 2

Experiment 1: Relative rate of responding in initial links, relative entries into terminal links, number of entries into each terminal link, and absolute response rates on initial link and terminal link schedules. Relative rates/entries equals total number of responses/entries to right alternative divided by total for both alternatives (Rel=R/R+L).

S	Session	Condition	C.O.D. (-sec.)	Terminal link schedules (-sec.)		Relative rate of response on right initial link	Relative entries into right terminal link	Number of entries into each terminal link		Absolute response rates on initial link (resp./min.)		Absolute response rates on terminal link (resp./min.)	
				Left	Right			Left	Right	Left	Right	Left	Right
S1	1	A	1	FI-30	FI-30	.43	.49	34	33	58.3	54.1	37.6	26.4
	2	"	"	"	"	.51	.50	38	38	66.1	65.8	21.0	20.8
	3	"	"	"	"	.53	.49	40	39	151.8	154.1	23.2	25.4
	4	B	"	"	MI-30	.48	.42	37	27	81.4	83.0	13.6	58.0
	5	"	"	"	"	.64	.53	34	38	44.8	53.5	5.4	26.8
	6	"	"	"	"	.67	.54	33	38	54.8	70.0	5.2	39.8
	7	C	"	"	AMI-30	.60	.55	34	42	108.3	113.7	8.4	36.2
	8	"	"	"	"	.52	.49	40	39	89.4	101.4	12.0	24.6
	9	"	"	"	"	.45	.49	40	38	103.4	118.9	15.2	32.8
	10	D	"	"	MI-30	.56	.50	43	43	124.6	107.0	17.4	50.0
	11	"	"	"	"	.49	.51	36	37	153.2	184.9	18.2	92.0
	12	"	"	"	"	.63	.50	35	35	87.6	130.6	17.6	60.8
S2	1	A	1	FI-30	FI-30	.48	.45	36	29	36.1	32.6	26.2	26.4
	2	"	"	"	"	.51	.51	33	35	34.8	36.5	18.6	23.8
	3	"	"	"	"	.53	.54	31	36	26.2	20.6	13.2	13.4
	4	C	"	"	AMI-30	.62	.62	25	41	29.8	22.9	9.6	9.4
	5	"	"	"	"	.48	.47	36	32	21.8	23.4	4.8	8.0
	6	"	"	"	"	.33	.26	48	17	14.1	22.6	4.6	7.2
	7	B	"	"	MI-30	.89	.93	5	63	67.0	21.2	25.2	11.0
	8	"	"	"	"	1.00	1.00	--	68	--	18.1	--	8.6
	9	"	"	"	"	1.00	1.00	--	70	--	18.6	--	7.3
	10	C	"	"	AMI-30	.81	.85	10	55	37.6	17.7	15.8	8.8
	11	"	"	"	"	.58	.55	34	42	29.8	27.7	7.2	10.0
	12	"	"	"	"	.53	.53	36	40	31.1	35.5	6.4	10.8

Table 2 - Cont'd.

S	Session	Condition	C.O.D. (-sec.)	Terminal link schedules (-sec.) Left	Terminal link schedules (-sec.) Right	Relative rate of response on right initial link	Relative entries into right terminal link	Number of entries into each terminal link Left	Number of entries into each terminal link Right	Absolute response rates on initial link (resp./min.) Left	Absolute response rates on initial link (resp./min.) Right	Absolute response rates on terminal link (resp./min.) Left	Absolute response rates on terminal link (resp./min.) Right
A3	1	A	1	FI-30	FI-30	.40	.50	39	39	88.5	87.9	98.5	103.5
	2	"	"	"	"	.55	.50	40	40	87.6	96.7	83.7	78.4
	3	"	"	"	"	.59	.49	41	40	80.9	74.0	60.6	60.7
	4	B	"	"	MI-30	.63	.50	39	39	58.7	56.7	53.5	62.7
	5	"	"	"	"	.53	.51	41	42	66.5	63.5	51.4	45.5
	6	"	"	"	"	.51	.49	40	39	69.0	66.0	46.8	47.6
	7	C	"	"	AMI-30	.46	.51	35	36	55.3	56.5	58.5	47.1
	8	"	"	"	"	.58	.50	40	40	63.7	63.6	67.8	63.0
	9	"	"	"	"	.43	.50	40	40	76.6	72.2	82.4	119.4
	10	B	"	"	MI-30	.56	.51	41	42	72.1	80.7	57.4	55.4
	11	"	"	"	"	.56	.49	41	40	110.3	122.5	113.1	115.9
	12	"	"	"	"	.41	.51	40	41	180.3	170.7	159.7	167.0
	13	D	"	"	FI-15	.44	.50	51	51	97.6	110.9	85.9	84.7
	14	"	"	"	"	.55	.50	50	50	104.3	104.2	82.2	81.3
	15	"	"	"	"	.42	.51	45	46	78.3	78.4	62.1	56.7
A4	1	A	4	FI-30	FI-30	.54	.52	38	42	170.6	164.3	142.8	148.5
	2	"	"	"	"	.49	.50	40	40	217.6	219.3	191.1	199.9
	3	"	"	"	"	.49	.51	40	41	214.7	221.3	196.9	193.3
	4	C	"	"	AMI-30	.50	.49	41	40	242.7	259.0	233.9	231.4
	5	"	"	"	"	.49	.50	41	41	260.5	260.8	245.7	252.2
	6	"	"	"	"	.51	.49	42	41	282.9	275.9	267.3	268.3
	7	B	"	"	MI-30	.49	.50	40	40	314.3	279.1	280.5	29[illegible].9
	8	"	"	"	"	.51	.50	42	42	316.8	298.4	299.1	295.5
	9	"	"	"	"	.48	.49	43	41	321.1	295.4	295.3	305.5
	10	C	"	"	AMI-30	.53	.50	51	51	365.2	351.3	311.1	320.3
	11	D	"	"	FI-15	.50	.50	51	51	352.6	336.2	306.9	319.6
	12	"	15	"	"	.52	.51	37	39	293.8	337.8	295.3	292.9

Table 3

Experiment 2: Sequence of experimental conditions

Subject	Condition	Number of Sessions	Initial Link Schedule	Terminal Link Schedule (in sec.) Left	Right
B1 & B2	A1	3	VI-10"	MI-30	AMI-30
	A2	"	FR-1	"	"
B3	A1	3	VI-10"	MI-30	AMI-30
	B	"	"	AMI-30	"
	A1	"	"	MI-30	"
	A2	"	FR-1	"	"
B4	A	3	VI-10"	MI-30	AMI-30
	B	"	"	AMI-30	MI-30
	A	"	"	MI-30	AMI-30
	C	"	"	"	FI-30
	D	"	"	AMI-30	"

Note: The experiment was terminated early for Subjects B1 and B2 due to indifference between terminal link alternatives. For Subject B3, preference was measured in comparison to a baseline phase; for Subject B4, preference was measured, in the first [illegible] sessions, by alternating the positions of the MI and AMI terminal link schedules.

Table 4

Experiment 2: Relative rate of responding in initial links, relative entries into terminal links, number of entries into each terminal link, and absolute response rates on initial link and terminal link schedules. Relative rates/entries equals total number of responses/entries to left alternative divided by total for both alternatives (Rel=L/R+L).

S	Session	Condition	Initial Link Schedules	Terminal link schedules (-sec.) Left	Right	Relative rate of response on left initial link	Relative entries into left terminal link	Number of entries into each terminal link Left	Right	Absolute response rates on initial link (resp./min.) Left	Right	Absolute response rates on terminal link (resp./min.) Left	Right
B1	1	A1	VI-10"	MI-30	AMI-30	.48	.49	36	38	312.6	340.5	303.4	303.6
	2	"	"	"	"	.51	.52	39	36	331.6	338.7	316.7	294.1
	3	"	"	"	"	.50	.50	38	38	326.5	350.3	326.4	306.4
	4	A2	FR-1	"	"	.48	.48	37	40	--	--	182.4	174.0
	5	"	"	"	"	.50	.50	45	45	--	--	207.8	192.6
	6	"	"	"	"	.51	.51	41	40	--	--	208.0	278.4
B2	1	A1	VI-10"	MI-30	AMI-30	.50	.50	34	34	76.3	84.8	70.2	79.1
	2	"	"	"	"	.55	.50	39	39	88.1	86.1	92.7	89.5
	3	"	"	"	"	.50	.51	40	39	100.2	99.3	99.5	97.7
	4	A2	FR-1	"	"	.46	.46	36	42	--	--	74.7	77.6
	5	"	"	"	"	.50	.50	41	41	--	--	113.7	102.8
	6	"	"	"	"	.54	.54	45	39	--	--	114.9	113.9
B3	1	A1	VI-10"	MI-30	AMI-30	.60	.56	40	32	238.3	239.7	97.4	110.3
	2	"	"	"	"	.58	.60	45	30	261.0	285.1	127.0	140.0
	3	"	"	"	"	.70	.56	45	35	243.9	253.7	115.0	120.4
	4	B	"	AMI-30	"	.58	.51	40	39	246.0	256.7	121.2	125.7
	5	"	"	"	"	.52	.50	39	39	195.8	208.4	93.8	95.6
	6	"	"	"	"	.59	.52	40	37	194.8	192.1	85.4	92.7
	7	A1	"	MI-30	"	.59	.51	39	37	196.7	207.6	84.9	87.5
	8	"	"	"	"	.54	.52	42	39	236.5	246.9	105.4	115.8
	9	"	"	"	"	.54	.52	41	38	223.7	229.5	98.6	108.3
	10	A2	FR-1	"	"	.61	.61	52	33	--	--	33.0	38.6
	11	"	"	"	"	.16	.16	14	72	--	--	11.4	5.3
	12	"	"	"	"	.00	.00	--	92	--	--	--	3.0

Table 4 - Cont'd.

S	Session	Condition	Initial link Schedules	Terminal link schedules (-sec.) Left	Right	Relative rate of response on left initial link	Relative entries into left terminal link	Number of entries into each terminal link Left	Right	Absolute response rates on initial link (resp./min.) Left	Right	Absolute response rates on terminal link (resp./min.) Left	Right
B4	1	A	VI-10"	MI-30	AMI-30	.40	.47	34	38	60.4	72.3	27.2	41.2
	2	"	"	"	"	.68	.56	39	31	67.4	37.0	38.1	28.8
	3	"	"	"	"	.64	.58	42	30	23.5	21.3	19.0	18.5
	4	B	"	AMI-30	MI-30	.64	.61	40	26	33.2	29.7	8.4	7.4
	5	"	"	"	"	.55	.63	45	26	21.8	33.8	3.0	4.0
	6	"	"	"	"	.91	.88	56	8	29.2	22.5	4.9	2.9
	7	A	"	MI-30	AMI-30	.82	.79	57	15	33.4	32.7	7.7	7.0
	8	"	"	"	"	.12	.14	10	60	27.4	30.1	5.6	4.8
	9	"	"	"	"	.13	.09	7	67	17.4	30.7	4.7	5.1
	10	C	"	MI-30	FI-30	.66	.64	44	25	31.5	28.0	6.3	7.8
	11	"	"	"	"	1.00	1.00	71	--	23.9	--	4.0	--
	12	"	"	"	"	.19	.21	15	55	27.7	30.0	7.2	5.4
	13	D	"	AMI-30	"	.68	.63	45	25	27.2	22.1	5.0	4.9
	14	"	"	"	"	.37	.86	62	10	24.6	25.7	3.3	6.7
	15	"	"	"	"	.93	.93	68	5	20.7	20.4	2.9	3.6

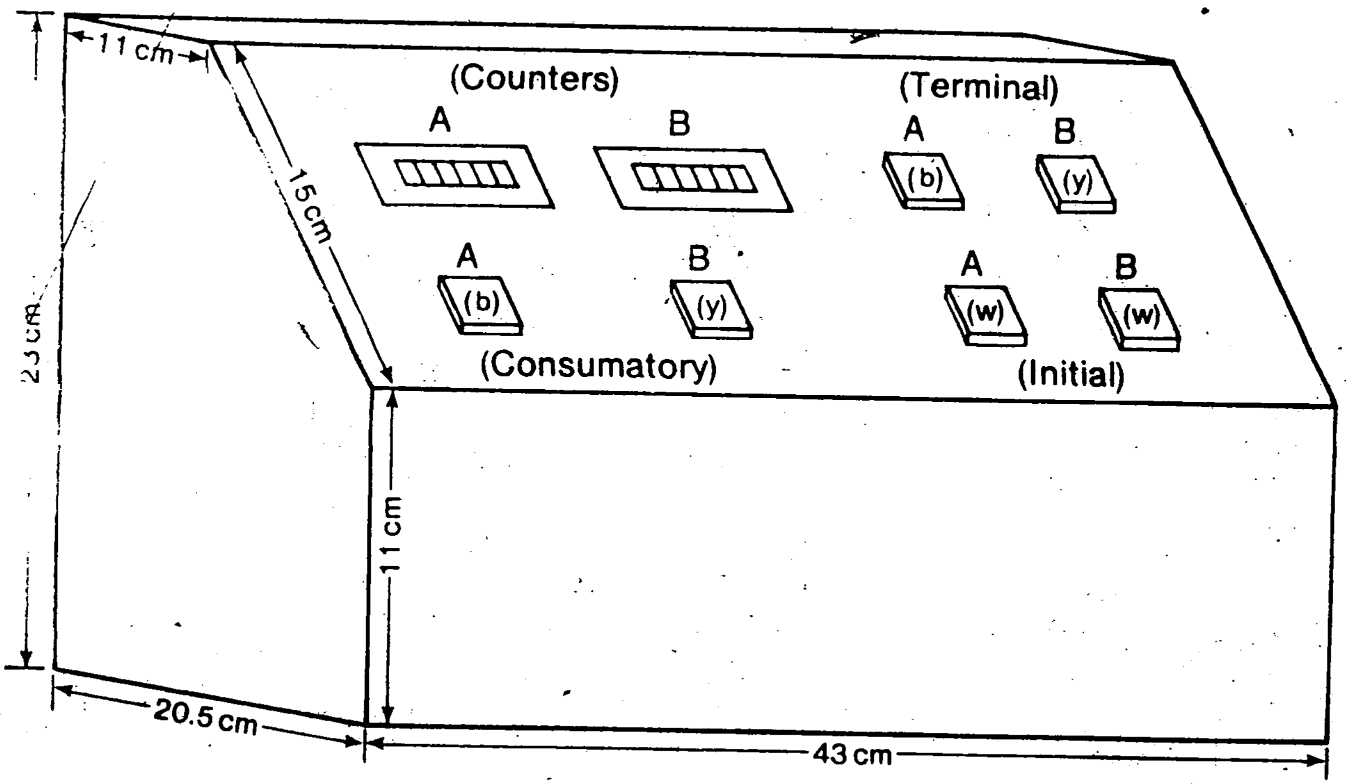

Figure 1: The response panel used in Experiments 1 and 2. The initial link buttons were both white, while the terminal link and consumatory response buttons were blue and yellow.

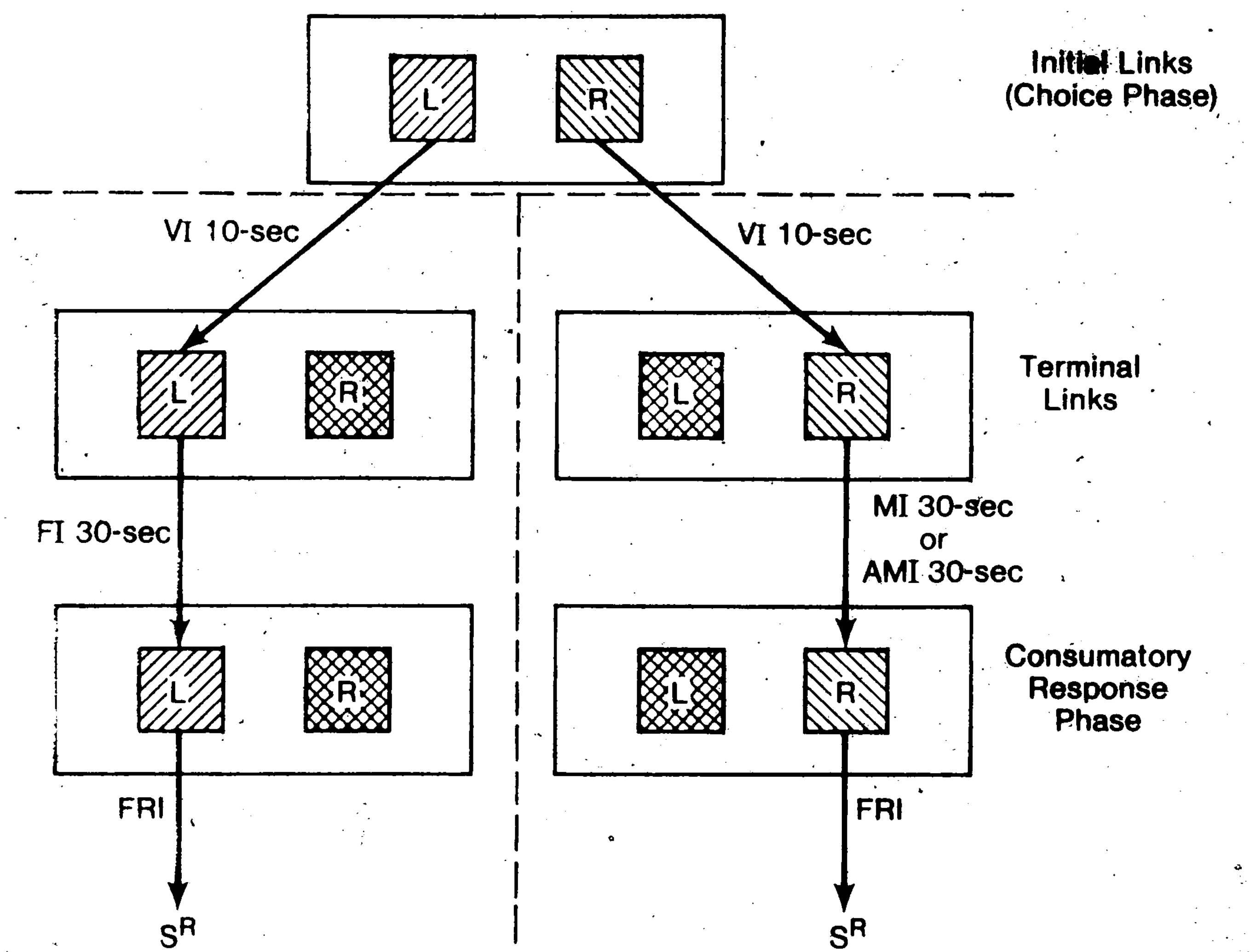

Figure 2: Diagram of procedure in Experiment 1. In the initial links, both alternatives are available. In the terminal links and consumatory response phase, only one alternative is available.

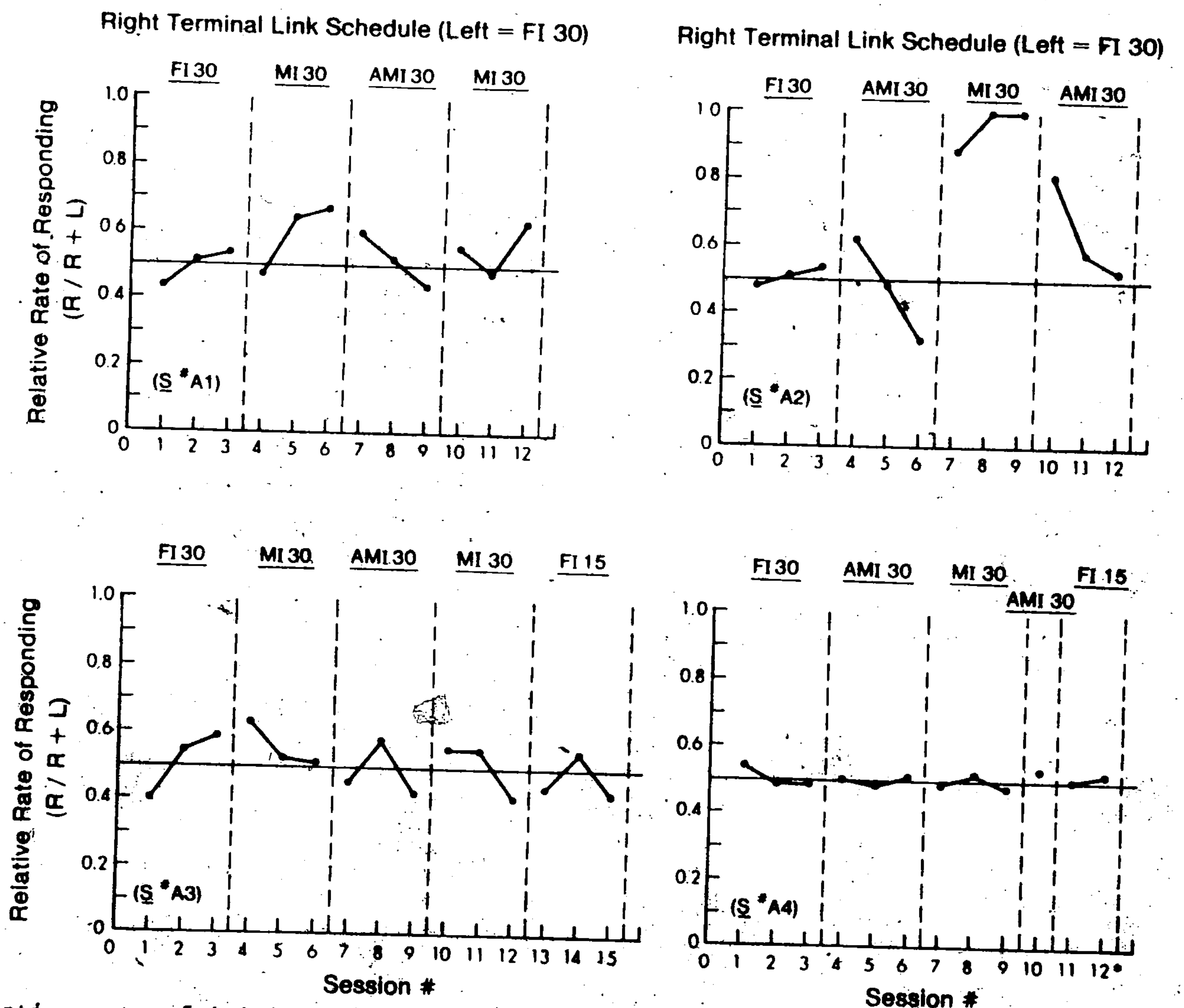

Figure 3: Relative rate of initial link responding to right alternative for each subject in Experiment 1. *C.O.D. increased to 15-sec. in session 12 for Subject A4.

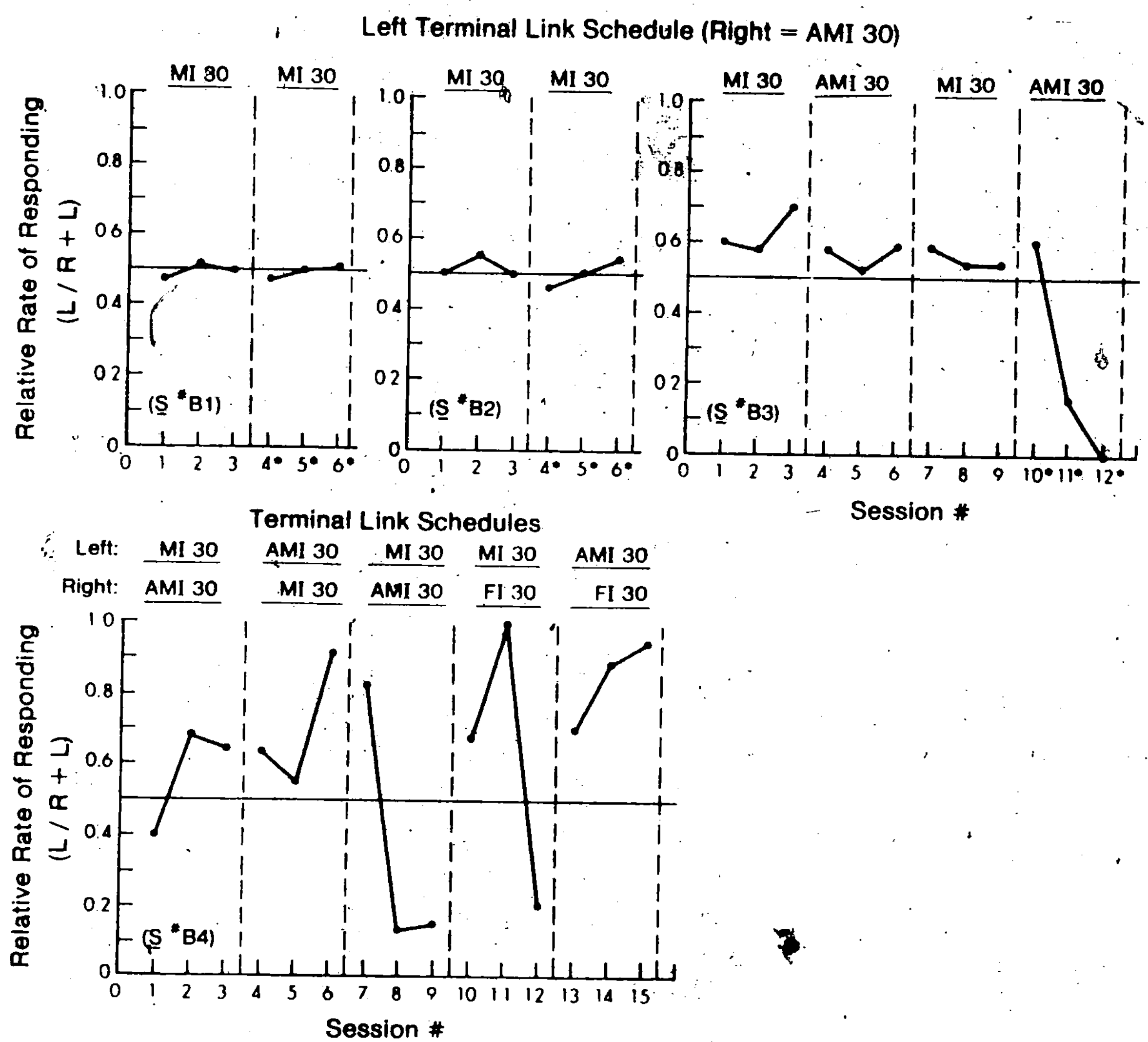

Figure 4: Relative rate of initial link responding to left alternative for each subject in Experiment 2.
*Initial link schedules reduced from VI-10-sec. to FR-1 for these sessions.

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Appendix A

Preference for Variable versus Fixed Schedules of Reinforcement: A Review of the Literature

Schedules of reinforcement may be categorized in several ways. The most basic distinctions are between ratio and interval schedules, and between variable and fixed schedules. The present paper reviews research which has generally shown that organisms' prefer variable over fixed schedules of reinforcement, although the mean rate of reinforcement on both schedules may be equal. First, however, it may be useful to outline the basic paradigms used in this research.

Preference Paradigms

The studies in this review have utilized two different paradigms for determining schedule preferences. The most common paradigm is the concurrent-chain procedure as first suggested by Autor (1969). In the initial links of the chain, the organism is presented with two stimuli, both associated with equal variable-interval (VI) schedules. Meeting the requirement on either alternative is reinforced by production of a second stimulus associated with another schedule of reinforcement. Meeting the requirement on this terminal link schedule then results in primary reinforcement. When a terminal link schedule is in effect the other alternative becomes inoperative. Thus, during the initial links of the chain, the organism chooses between two mutually exclusive terminal link schedules, for example, a fixed-interval (FI) schedule and a VI schedule. Preference for terminal link schedules is typically measured by relative rate of responding on the initial link schedules.

An advantage of the concurrent-chains procedure is that it separates rate of responding for a schedule (i.e., initial link responding) from rate of responding on a schedule (i.e., terminal link responding). Rate of responding on a schedule is invalid as a measure of preference since it may be influenced by characteristics of the schedule itself. For example, ratio schedules typically generate higher response rates than interval schedules, because ratio schedules provide intermittent reinforcement for shorter interresponse times (Ferster & Skinner, 1957). Thus, higher response rates on ratio as opposed to interval schedules may be a function of schedule characteristics, and do not necessarily indicate preference for that schedule. An analogous situation would be to incorrectly assume that cleaning house is preferred to watching television, because the former has a higher rate of activity.

A second paradigm, which has been employed to measure preference for variable ratio (VR) versus fixed ratio (FR) schedules, is the switching procedure devised by Findley (1958). Responses on a change over (CO) alternative change or switch the schedule of reinforcement in effect on a second alternative. Preference is measured as the relative frequency of change-overs from one schedule to another. For example, if the procedure is arranged so that an FR schedule is presented at the start of each trial, but the subject continually switches to an alternative VR schedule, then one can conclude that the subject prefers VR over FR. Similar to the concurrent-chains procedure, this procedure separates responding for a schedule (i.e., change-over responding) from responding on a schedule. In addition, Findley has shown that the degree of preference can be manipulated by changing the response requirement on the CO alternative. Increasing the requirement tends to reduce the amount of switching from one schedule to another, and increases preference for the schedule presently in effect.

Preference for VI versus FI Schedules

All of the research on preference for VI versus FI schedules h[illegible]ed the concurrent chains paradigm. In the first study [illegible] described, the procedure will be outlined in some de[illegible] to facilitate clarity. Following this, discussions [illegible] other studies will emphasize [illegible] those differences from [illegible] which [illegible] significant.

Preference for VI [illegible] s[illegible]us [illegible] schedules [illegible] first investigated by [illegible] a concurrent-chains procedure, pigeons chose between two response keys, both transilluminated with a white light. Both keys were programmed on independent VI 60-sec schedules. Meeting the schedule requirement on the right key changed the key color to yellow, and resulted in two successive presentations of a terminal link FI schedule. Responding on the FI schedule was reinforced by three seconds access to grain. A similar sequence was arranged on the left key, except that the terminal link sometimes consisted of VI schedules. The left/right terminal link schedules in each condition were VI 15-sec/FI 15-sec, VI 15 sec/FI 4-sec, VI 15-sec/FI 8-sec, and FI 15-sec/FI 4-sec in that order. Earlier research had shown that pigeons would match rate of responding of initial link alternatives to rate of primary reinforcement on the terminal link alternatives, when both terminal links consisted of VI and/or VR schedules (Autor, 1969; Herrnstein, 1964a). In comparing the VI and FI schedules, however, Herrnstein found a consistent bias for the VI alternative. Thus, even when the arithmetic means of both schedules were equal, i.e., VI 15 sec/FI 15 sec, the four birds emitted over 70% of their initial link responses on the key leading to the VI alternative. If subjects had been matching rate of responding to rate of reinforcement, responding should have been equally distributed between the two alternatives.

To account for the bias towards the VI alternative, Herrnstein (1964b) suggests that pigeons may "weight the shorter intervals of the variable interval schedule more than the longer" (p. 181). Thus, the assumption of arithmetic averaging of intervals in VI schedules may be an inappropriate description of their value relative to FI schedules. Because the shorter interreinforcement intervals in the VI schedule may exert a disproportionate influence on responding, a VI schedule is not equivalent to an FI schedule with the same arithmetic mean. Herrnstein also suggests that it may be possible to derive a transformation rule for interval values which would predict the observed preferences, but found that a logarithmic transformation was inadequate. (A logarithmic transformation results in a geometric mean of interval values which weights shorter intervals more heavily.) Finally, Herrnstein notes the similarity of the results to gambling behavior in humans. In gambling, the slight possibility of a relatively immediate gain is highly attractive to many individuals. They prefer to gamble rather than invest their money in more conservative ventures which, though more certain, pay off only after a much longer interval.

Killeen (1968) attempted to derive a specific transformation rule which would describe preference for VI over FI. In Experiment 1, the terminal link alternatives consisted of single presentations of a VI schedule and an FI schedule of primary reinforcement. For VI 23-sec, 54-sec, and 31-sec schedules, in that order, FI schedules were found which resulted in equal responding for both alternatives. For the group data, a transformation rule was then derived which would predict such equivalence. The transformation was based on a power function of the form:

$$M(y^r) = 1/N \sum_{i=1}^{N} y_i^r$$

where $M(y^r)$ is the mean interval of the schedule, y_i is the value of the ith component interval of the schedule, N is the number of components, and r is a parameter. As r becomes more negative, shorter component intervals are weighted more heavily. Killeen found that a harmonic transformation of the intervals (r=-1), i.e., a reciprocal transformation of the intervals, was most appropriate to describe his results. In other words, the pigeons were indifferent between VI and FI schedules with equal harmonic means, although the FI schedule always had a smaller arithmetic mean. This transformation seemed to account for Herrnstein's (1964b) data also. Experiment 2 provided further support for the validity of the harmonic transformation. Both terminal link alternatives were VI schedules. The number and size of the short versus long component intervals in each schedule was varied so that one schedule had a longer arithmetic mean but a shorter harmonic mean than the other. As expected, relative rate of responding in the initial links matched the harmonic rate and not the arithmetic rate of reinforcement.

Davison (1969) examined preference for FI versus mixed-interval (MI) schedules of reinforcement. (A mixed schedule can be considered as a type of VI schedule which controls for the number and length of component values. For example, a two-value MI 30-sec schedule may consist of 15- and 45-sec intervals presented in random order. This can also be referred to as a "mixed FI 15-sec FI 45-sec" schedule.) The concurrent-chains procedure was similar to Killeen's (1968) except that the initial link alternatives were separated by a 0.5-sec change-over delay (COD). [A COD is commonly used in concurrent schedules to prevent adventitious reinforcement of switching behavior, but is not commonly employed in the concurrent-chains procedure (Catania, 1966).] Across conditions, an MI 30-sec schedule, consisting of 15- and 45-sec components, was compared to 30-, 10-, 20-, 15-, and 25-sec FI schedules, in that order. For both individual birds and group data (N=5), Davison found that the reciprocals of the intervals transformed to the third power (r=-3) best described the data. This cubic transformation weights the shorter intervals more heavily than does the harmonic transformation suggested by Killeen.

Davison (1972) investigated whether number of component intervals would effect preference for MI versus FI. The procedure was basically identical to Davison (1969), but with no COD in the initial-links. Various combinations of FI schedules, ranging in value from 10- to 30-sec, were compared with MI 30-sec schedules containing either two, three, or seven component intervals. In each of these MI schedules, the shortest and longest components were 15- and 45-sec respectively. The results from six pigeons indicated that the number of component intervals did not effect preference. This also means that the number of times the shortest interval was presented also had no effect on preference. Davison found that preference in all conditions was best described by the mean of the reciprocals of the intervals squared (r=-2). This inverse square transformation weights the shorter intervals more than Killeen's (1968) harmonic transformation, but less than Davison's (1969) cubic transformation. In accounting for Killeen's data, Davison notes that Killeen used VI schedules which contained extremely short component intervals (3-sec) compared to the 15-sec interval in his own MI schedule. Thus, the length of the shortest interval may be a critical factor in determining the proper transformation; with extremely short components, a harmonic transformation may be most appropriate. Davison also suggests that the cubic transformation obtained in his earlier study may be due to the use of a COD procedure. For example, Shull and Pliskoff (1967) found that, with concurrent schedules, a COD increases preference for the alternative providing the greater rate of reinforcement. Similarly, in the Davison (1969) study, the COD may have enhanced preference for the MI alternative, thereby altering the appropriate transformation.

Hursh and Fantino (1973, Experiment 1) used a concurrent-chains procedure to investigate preference for MI versus FI when the shortest interval in the MI alternative was varied. Across conditions, the FI schedule varied between 10- and 50-sec, while the MI schedule consisted of a long interval of 60-sec and a short interval of either 10-, 20-, or 30-sec. It was predicted that the appropriate transformation rule would vary as the shortest interval in the MI schedule varied. This hypothesis, however, was not supported. Across all conditions, the data was best described by Davison's (1972) inverse square transformation (r=-2). In fact, this transformation accounted for 91% and 96% of the variance for individual birds, and 93.5% of the group variance. Hursh and Fantino conclude that the inverse square transformation appears to be quite general. They do suggest, however, that for VI schedules with very short components, as in Killeen (1968), the harmonic transformation may be more appropriate.

Navarick and Fantino (1972) tested whether preference for terminal link VI versus FI schedules would be "transitive" to comparisons with a third schedule. In one procedure, FI schedules were found which were equally preferred to VI 23- and 54-sec schedules. These VI and FI schedules were then each compared to an FI 20-sec schedule. "Strong stochastic transitivity" would hold if the equivalent VI and FI schedules were equally preferred to the FI 20-sec schedule. In tests involving the VI 23-sec schedule, transitivity held for three out of four birds; however, zero out of three birds demonstrated transitivity in tests involving the VI 54-sec schedule. A similar result was obtained with a second procedure: VI and FI schedules which were equally preferred over a standard FI schedule were not always equivalent when compared to each other. Such intransitivity was also found in comparisons involving VR and FR schedules. Navarick and Fantino suggest that the results indicate that variable schedules are substantially different from fixed schedules, and that a single general transformation rule to equate VI and FI schedules may not be possible (see also Navarick & Fantino, 1975).

Schrader and Rachlin (1976) examined the effect of signaled reinforcement on preference for VI versus FI. The values for both VI and FI schedules were 30-sec, 15-sec, 6-sec, and 2.5-min in that order. To control for length of terminal links, the VI terminal link was always equal in length to the FI terminal link, and the number of VI reinforcements varied randomly between zero and two. In the signaled condition, the occurrence of reinforcement in each terminal link was preceded by a brief change in key color. While previous research had shown that rats prefer signaled over unsignaled shock (Badia, Harsh, & Coker, 1975), Schrader and Rachlin found no effect of signaled reinforcement on preference for VI over FI schedules. They had predicted that the signal would effect preference by eliminating the differences between schedules in predictability of reinforcement. However, the signal did influence terminal link responding; response rates preceding the signal were relatively slow, but increased considerably when the signal was presented. In the unsignalled conditions, response rates varied little throughout the intervals, especially for the VI schedules. Interestingly, as the values of the VI and FI schedules decreased, preference for the VI schedule also decreased. For example, three out of four birds emitted more than 90% of their initial link responses to the key leading to the VI schedule when the mean schedule values were 30-sec or greater. With the 6-sec schedules, however, responding for the VI alternative dropped to between 60% and 70%. This effect would be expected on the basis of a heavier weighting of shorter intervals; the short component in the VI schedule, e.g., 3-sec, would be that much shorter than the FI schedule interval as the values of these schedules increased, e.g., 6-sec to 30-sec. This assumes that the short component in the VI alternative remained relatively constant as the mean length of the schedule increased. Unfortunately, Schrader and Rachlin do not report what the VI components were.

Frankel and Vom Saal (1976) examined the effect of interval "predictability" on preference for MI versus FI. Their research was based on an earlier study by Bower, MacLean, and Meacham (1966) who found that pigeons preferred multiple-interval over mixed-interval schedules. (A multiple schedule differs from a mixed schedule in that each component is accompanied by a distinctive stimulus.) Thus, pigeons preferred the terminal link where interval values were made predictable by correlated, as opposed to uncorrelated, terminal link key colors (see also Fantino & Moore, 1980; Green, 1980; and Hursh & Fantino, 1974). On the basis of this result, Frankel and Vom Saal predicted that pigeons would prefer a multiple-interval over an FI schedule more so than an MI over an FI schedule. Using a concurrent-chains procedure with VI 60-sec initial links, there was a slight but consistent effect in the predicted direction for all seven birds. They also replicated the Bower et al. finding, but only when the initial links were reduced from VI 60-sec to FR1 as used in the original study. This last finding concurs with Hursh and Fantino (1974) who note that decreasing the length of the initial link schedules will increase the preference shown for one terminal link schedule over the other.

Preference for VR versus FR Schedules

Fantino (1967) used a concurrent-chains procedure to examine preference for mixed-ratio (MR) versus FR schedules of reinforcement. The range of the MR schedule components was manipulated (the short/long intervals were either 1/99, 10/90, or 25/75), as well as the number of MR components - either two (1/99) or three (1/50/99). All five pigeons preferred MR over FR schedules of equal mean value. In addition, preference for MR generally increased as the range in component values was increased; relative rate of responding for MR was sightly below 60% with the 25/75 components and above 70% with the 1/90 components. The number of component values in the MR schedule had no effect on preference, matching Davison's (1972) results with MI versus FI schedules. Finally, Fantino determined that relative rate of responding in the initial links was closely approximated by the relative geometric rates of reinforcement in the terminal links.

As part of a series of experiments on preference for informational stimuli, Hendry (1969) compared a VR schedule and two-value multiple and mixed-ratio schedules with various FR schedules. A concurrent-chains procedure was used with FR10 initial links. Unlike Frankel and Vom Saal's (1976) results with MI schedules, discussed previously, Hendry found that preference over FR was not reliably greater for the multiple schedule than for the mixed schedule. The multiple schedule was, however, preferred over FR more so than VR was preferred over FR. In addition, the multiple schedule was strongly preferred over the mixed schedule in a direct comparison of the two. Hendry interprets preference for the multiple schedule in terms of the reduction of "uncertainty"; the multiple schedule's key colors were correlated with the component values of the schedule which were thereby made more predictable. Hendry also attempted to derive a transformation rule to describe his data, but found that a harmonic transformation of reinforcement rates was generally inadequate.

Sherman and Thomas (1968) used a switching procedure to examine preference between nine FR schedules with correlated stimuli (i.e., a nine-component multiple-ratio schedule) and an MR schedule consisting of the same nine values presented with the same stimulus. The schedule values were 1, 30, 60, 90, 120, 150, 180, 210, and 240. The pigeons could either complete the FR schedule presented to them, or they could peck the CO key and switch to the MR schedule. Once a subject began responding on a schedule, the CO key was turned off and the subject was locked into that schedule. When only one response on the CO key was required to switch schedules, both birds switched to the MR alternative at an extremely high frequency; they remained with the FR schedule only with the two or three shortest FR values. However, in order to maximize overall rate of reinforcement, subjects should have switched to the MR schedule only when the FR value was greater than 120. Thus, MR was preferred over FR more than would be predicted by relative rates of reinforcement. In accordance with Findley (1958), Sherman and Thomas also found that as the switching requirement increased, preference for the MR schedule decreased.

Preference for a multiple-ratio versus an FR schedule was investigated by Boeving and Randolph (1975). The initial links consisted of FR10 schedules. The terminal links consisted of an FR30 schedule, and a multiple-ratio schedule with component values of 5 and 80. Across conditions, the smaller component was reduced in probability of occurrence from .50 to 00. The three pigeons demonstrated almost exclusive preference for the multiple schedule, except when the probability of the shorter component was reduced to 00. At that point, they showed exclusive preference for the FR alternative. The authors interpret the pigeons preference for the multiple schedule as an instance of gambling for the shortest path to reinforcement, even when the possibility of winning the gamble was extremely small.

Rider (1983b) allowed rats to choose between equiprobable MR and FR schedules of food reinforcement. These schedules were presented either as concurrent schedules, or as terminal link alternatives in a concurrent chains procedure with FR1 initial links.

Preference was measured as proportion of responses on each schedule in the concurrent procedure, and as proportion of initial link choice responses in the concurrent-chains procedure. Six out of seven rats displayed systematic schedule preferences. Five rats consistently preferred an FR35 schedule over an MR50 schedule (components of .1/99) in the concurrent procedure, but showed a reversed preference in the concurrent-chains procedure. The seventh rat showed a similar trend when FR values were systematically varied between 25, 35, 50, and 80. The FR schedules were consistently preferred in the concurrent procedure, with the exception of the FR80 alternative, while the MR50 alternative was generally preferred in the concurrent-chains procedure. These results demonstrate that responding *on* a schedule is not equivalent to reponding *for* a schedule, and appears to justify the use of the concurrent-chains procedure as a measure of schedule preference.

Weiner (1966) used the switching procedure to examine preference in adult humans (N=4) for VR40 versus FR40 schedules of points delivery. After reinforcement on one schedule, say FR, the other schedule, VR, would be automatically presented. A response on the CO key was thus necessary to reinstate the previous schedule. Weiner found no preference for either VR or FR. A reason for this may be that he instructed the subjects to "get the highest score possible". Relative to this strategy, responding on the CO key would waste time and reduce overall reinforcement; therefore, switching would not occur. This assumes that subjects discriminated the VR and FR schedules as equivalent in mean rate of reinforcement. In other conditions of this experiment, subjects did show preference for an FR10 over an FR40 schedule, and for an FR40 schedule which resulted in 400 points as opposed to an FR40 which resulted in 100 points. Both of these preferences are consonant with the instruction to maximize overall points.

Repp and Deitz (1975) used a switching procedure to investigate human preference for VR60 versus FR60 schedules of token reinforcement. Each token, when earned, could be immediately exchanged for a penny. The VR and FR schedules alternated automatically after each reinforcement, and a switching response was required to reinstate the previous schedule. When preferences stabilized at a certain CO requirement, the requirement was increased by one response. This was done until switching behavior was eliminated. The subjects, two boys and two girls age 10 to 12, all switched to the VR schedule more often than to the FR schedule. The relative change-overs to VR as opposed to FR were always greater than .60 as long as switching behavior was being engaged in. All subjects abruptly stopped switching, however, once the CO requirement requirement reached a certain level: 9 responses with one subject, and 11, 13, and 17 responses with the other three. This result conflicts with previous research (e.g., Findley, 1958; Sherman & Thomas, 1968) which found that switching would gradually decrease as the CO requirement increased. Finally, the question arises as to why preference for VR over FR was found with humans in this study and not in the similar study by Weiner (1966). One factor may be that Repp and Deitz did not specifically instruct subjects to earn as much as possible. As previously discussed, this instruction may disrupt switching, since it would waste time and reduce overall earnings. The other factor may be the relative ages of the subjects; Weiner used adults while Repp and Deitz used children. Research has shown that age is inversely related to preference for immediate over delayed reinforcement (e.g., Mischel & Metzner, 1962). Thus, children may be more likely than adults to "weight" the shorter intervals, i.e., the more immediate reinforcement, in the VR schedule more heavily. This would then result in preference for the variable alternative.

Preference for Fixed versus Variable Delay of Reinforcement

Two early studies (Logan, 1965; Pubols, 1962) examined preference for mixed versus fixed delay of reinforcement using maze running procedures with rats. Pubols found that rats consistently chose that arm of a Y maze where reinforcment was delivered after a mixed delay as opposed to the other arm where reinforcement was delivered after a constant delay. The component values of the mixed delay were zero seconds and twice the value of the constant delay, and were presented in random order. The rats preferred the mixed delay side even when reinforcement was presented only during the short component, i.e., immediate reinforcement on 50% of trials, and long delay but no reinforcement on the other 50% of trials. Logan varied both amount and delay of reward, and also found preference for mixed over fixed delay. Six out of seven rats preferred a mixed delay alternative, with component delays of 0- and 15-sec (mean = 8-sec), over a constant delay of 8-sec.. With three of the rats, preference for the mixed alternative was exclusive. The results also indicated that the mixed delay was approximately equivalent to a constant delay of 7-sec; at that value, half of the rats preferred the mixed alternative while the other half preferred the constant alternative.

Cicerone (1976) used a standard concurrent-chains procedure to examine preference for mixed versus constant delay of reinforcement. Pigeons were presented various combinations of mixed and constant delays, and, across conditions, the range of the mixed delay values was increased. When the constant delay was 8-sec, four pigeons consistently preferred the mixed delay alternative when it consisted of 2- and 14-sec components, but not when it consisted of 6- and 10-sec components. Two other pigeons were exposed to a constant delay alternative of 30-sec, and a mixed delay alternative with either 15/45, 5/55, or 0/60-sec components. The mixed alternative was consistently preferred only for the two broadest ranges; for the 5/55 and 0/60 mixed delays, the respective relative rates of responding in the initial links were .69 and .97 for one subject, and .93 and .99 for the other subject.

Rider (1983a) examined preference for mixed versus constant delay, and varied the probability of the short component of the mixed delay. Rats were run on a standard concurrent-chains procedure, with the addition of a 2-sec COD in the initial links. The constant delay was 15-sec for three subjects, and 30-sec for two subjects. The mixed delay components were always 0.2-sec and twice the length of the constant delay. Across conditions, the probability of occurrence of the short component was .00, .10, .25, .50, .75, .90, and 1.00. In all cases, relative rate of initial link responding was greater for the mixed alternative when the probability of the short component was above .25. In addition, preference for the mixed alternative was much greater for the two rats exposed to the longer delays. A harmonic transformation of interreinforcement intervals, similar to Killeen (1968), was attempted, but was found to be inadequate.

Substantive Issues

The preceding studies have generally found that variable schedules are preferred over fixed schedules of reinforcement. With respect to factors determining such preference, a good deal of emphasis has been placed on Herrnstein's (1964b) hypothesis that preference is a function of the heavier weighting of the shorter components in the variable schedule. A number of transformation rules have been attempted to precisely describe this relationship, but, as Frankel and Vom Saal note, "no consistent transformation has been found which is adequate to account for more than a limited set of data" (Frankel & Vom Saal, 1976). Rider (1983a) suggests that it may be unreasonable to expect that a single model would ever be entirely adequate. He supports Navarick's and Fantino's (1972) opinion that the failure of schedule preferences to show strong stochastic transitivity implies that any specific transformation must necessarily be limited in its applicability. Of relevance to this, Herrnstein (1981) has recently suggested a theoretical model regarding preference for large delayed versus small immediate reinforcers. Built into the model is the assumption that the effects of delayed reinforcement on response strength may vary as a function of experiential factors and genetic differences between and within species. In other words, the subject's "weighting" of the interreinforcement intervals can vary as a result of a number of factors, and cannot be expected to remain constant. Thus, Herrnstein's model also argues against the possibility of finding a precise, yet generally applicable, transformation rule for describing schedule preferences.

Variable schedules differ from fixed schedules not only in the length of the component values, but also in the predictability of those values. Predictability is here defined as the degree to which the components are correlated with some preceding stimulus or event. Fixed schedules are inherently more predictable than variable schedules. In addition, multiple schedules, where a separate cue is provided for each component of the schedule, are more predictable than mixed or variable schedules, where all components are presented with the same cue. Frankel and Vom Saal (1976), as well as Hendry (1969), found some evidence that multiple schedules are preferred over fixed schedules more so than mixed schedules are. Frankel and Vom Saal interpret this result as indicating that the nonpredictability of component values in the mixed schedule only serves to reduce preference for that schedule. In other words, the mixed schedule is preferred solely on the basis of the heavier weighting of the shorter component values, and the nonpredictability only detracts from such preference. A problem with this interpretation is that, in their concurrent chains procedure, the predictive cues of the multiple schedule were available only after that schedule had been selected, i.e., only after the terminal link was entered. Thus, during the initial link choice phase, the upcoming component on the multiple schedule was still as nonpredictable as in the mixed schedule. Thus, even in selecting the multiple schedule, the pigeons were still "gambling" on which component would occur. In this manner, preference for the multiple schedule seems to be an instance of "wanting to know the outcome of the gamble" as soon as possible, rather than trying to avoid the gamble. Indeed, Herrnstein (1964b) and Boeving and Randolph (1975) note the direct similarity of preference for variable over fixed schedules to gambling behavior. In addition, Sherman and Thomas (1968) demonstrated that pigeons would reliably switch from all but the shortest FR components of a multiple schedule to a nonpredictable mixed schedule even when switching reduced the rate of reinforcement. Their results imply that preference for the variable schedule is a direct function of gambling for the shortest path to reinforcement.

A third issue concerns the generality of preference for variable over fixed schedules across species, notably to humans. Only two studies have used human subjects (Repp & Deitz, 1975; Weiner, 1966), and the results of these studies have been inconclusive. Yet, Emerson (1972) has hypothesized that preference for variable over fixed schedules of reinforcement may be an important factor in human social interaction. Individuals who deliver social reinforcement on variable schedules may exert greater influence over others and come to dominate social relationships. Thus, research on schedule preferences in humans may lead to understanding some important determinants of human behavior. Relative to this possibility, however, the efforts to conduct such research have been inadequate.

Conclusion

Research was reviewed concerning preference for variable over fixed schedules of reinforcement. Such preference appears to be a consistent finding in lower animals, and seems to be a function of a tendency to "gamble" for the shorter path to reinforcement available with the variable alternative. It was noted, however, that research with humans in this area has been inadequate, and the studies which have been conducted have not yielded consistent results. Interestingly, Wearden (Note 1) believes that much of the animal research in operant conditioning may have little relevance to human behavior. Thus, it is important that research be carried out to directly determine whether schedule preferences found in laboratory animals do indeed have applicability to humans.

Reference Notes

1. Wearden, J.H. Personal communication. July, 1983.

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Appendix B: Questionnaires Used in Experiment 3

First questionnaire:

Subject #___

This study is concerned with individual preferences. It consists of filling out a short questionnaire, for which you will be paid $10.00. Part of the study, however, deals with the manner in which you will be paid the $10.00. More specifically, there are two alternative ways in which this money can be paid to you:

> Alternative A: You will receive the money in one month's time.

> Alternative B: You will receive the money either today or in two month's time. This will be determined by a coin flip such that you have a 50% chance of receiving the money today versus in two months.

(Please note that whichever alternative you select, you will be paid the money. The two alternatives differ only in terms of when you will receive the money.)

Please indicate how you wish to be paid by placing a checkmark in the appropriate space below:

Alternative	Time of Payment	Choice (X)
A	In one month	(__)
B	Either today or in 2 months (to be determined by coin flip).	(__)

Second questionnaire:

Subject #___

You ~~have now~~ made your choice between the two methods of payment, and your answers to the following items will have no further bearing on that choice. Nevertheless, please answer the following items as accurately
as possible.

For each item, please rate your degree of preference by circling the appropriate number on the rating scale provided.

For example:

Slightly prefer 1 2 3 4 5 6 (7) Strongly prefer

(where a rating of 7 indicates strong preference).

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1. Would you prefer to receive the $10.00 today rather than in one month?
   Yes __ No __ If you answered yes, how strong is this preference?

Slightly prefer 1 2 3 4 5 6 7 Strongly prefer

2. Would you prefer to receive the $10.00 in one month rather than in two months?
   Yes __ No __ If you answered [illegible] how strong is this preference?

Slightly prefer 1 2 3 4 5 6 7 Strongly prefer

3. Would you prefer to receive the $10.00 today rather than in two months? Yes __ No __
   If you answered [illegible] how strong is this preference?

Slightly prefer 1 2 3 4 5 6 7 Strongly prefer

In a couple of sentences, outline your reason [illegible] the method of payment that you did.