HUMAN FIXED-INTERVAL PERFORMANCE WITH CONCURRENTLY PROGRAMMED SCHEDULES: A PARAMETRIC ANALYSIS

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Young adults pressed a lever for points, exchangeable for money, programmed on concurrent schedules in which one component was a fixed-interval and the other component either a fixed-ratio (Experiment 1) or a differential-reinforcement-of-low-rate (Experiment 2). Two general patterns of fixed-interval responding, postreinforcement pause or constant rate, occurred in both experiments as a function of the parameter values of each component. Also patterns of interaction between the component schedules developed, in which responding or point delivery on one component appeared to be discriminative for responding on the other component. Once a pattern of responding was established, it tended to persist when the parameter values of the schedule were changed. On many schedules, subjects with an experimental history responded differently than did naive subjects, although certain schedule values were resistant to the history effects. The role of verbal strategies in mediating history effects was discussed.

Key words: concurrent FI-DRL, concurrent FI-FR, history effects, lever press, humans

An important factor in performance on fixed-interval (FI) or other fixed-duration schedules is the concurrent availability of other responses and reinforcers, whether or not they are specified and measured by the investigator (de Villiers, 1977; Herrnstein, 1974). A number of classes of behavior occurring in the interim between scheduled reinforcers has been identified, each a function of different variables. Certain responses, such as pecking by a pigeon or licking by a rat, may be induced in respondent fashion by delivery of the reinforcer (see review by Staddon, 1977). Other responses, such as counting (Laties & Weiss, 1963) or tapping a nonfunctional key (Bruner & Revusky, 1961), by humans, may be adventitiously reinforced. Finally, interim responses may be controlled by concurrent schedules of reinforcement that are explicitly programmed (Poppen, 1972).

That a temporally spaced response pattern (i.e., a post-reinforcement pause or PRP) is affected by interim behavior is demonstrated by studies that have manipulated the occurrence of such behavior. Physical restraint with

rats (Glazer & Singh, 1971) and very small experimental chambers with pigeons (Staddon, 1977), which prohibit grooming and locomotion, have resulted in constant rates of responding on temporal schedules. A concurrent covert subtraction task has produced a similar effect in some humans (Laties & Weiss, 1963). A concurrently programmed differential-reinforcement-of-low-rate (DRL) schedule resulted in a constant rate of FI, and a concurrent fixed-ratio (FR) resulted in a PRP FI pattern with humans (Poppen, 1972). One purpose of the present study was to study further the pattern of responding on FI schedules as a function of concurrently programmed FR (Experiment 1) and DRL (Experiment 2) schedules.

Another factor influencing performance on FI schedules is the subject's reinforcement history, the effect of prior schedules on performance on subsequent schedules. In studies with human subjects, Weiner (1964, 1969) found that an experimental history of responding on DRL schedules resulted in the PRP FI pattern, whereas a history of responding on FR resulted in high constant rates on FI. Poppen (1972) noted that history effects may occur in a concurrent situation but presented no systematic data. A second purpose of the present study was to identify characteristic patterns of responding on concurrent schedules containing an FI component and to examine the per-

This research was supported by grant IDMH 427-11 from the Illinois Department of Mental Health. Appreciation is extended to Bercedis Peterson for her assistance in data collection and analysis. Address reprint requests to Roger Poppen, Rehabilitation Institute, Southern Illinois University, Carbondale, Illinois 62901.

sistence of such patterns when the schedules were changed.

EXPERIMENT 1 HUMAN PERFORMANCE ON CONCURRENT FI FR SCHEDULES

Poppen (1972) found that when a FR 100 schedule was programmed concurrently with a FI 60-sec schedule, human subjects typically made about 300 responses per min on the FR component and changed over to FI after they had obtained three reinforcers on FR. It appeared that the delivery of FR reinforcers functioned as discriminative cues correlated with the passage of time on the FI. If the schedule values were such that it was not possible to complete a ratio within the time period of the FI, it would still be possible for subjects to aid discrimination of the FI period by responding on the FR key. Human subjects have shown a pattern of responding on an alternative key to assist temporal discrimination in DRL schedules (Bruner & Revusky, 1961; Poppen, 1972). Would this pattern occur on a conc FI FR schedule?

LaBounty and Reynolds (1973) studied conc FI FR schedules in pigeons. With a FI 4-min, and FR's of 100, 150, or 200, subjects pecked the ratio key at constant rates during the early part of the interval, changing over to the FI component only after ratio completions. More sustained FI responding occurred later in the interval. Unlike human subjects, pigeons changed over to FI after completing each ratio even though the interval had not timed out and occasionally spent an entire interval responding only on the FI key. With larger FR's (300 and 450) pigeons seldom completed a ratio without changeovers and the pattern of response varied widely across animals.

Experiment 1 investigated the pattern of response on conc FI FR schedules and the effects of training with one set of schedule parameters on performance on subsequent schedules.

METHOD

Subjects

Five female and seven male university students, ranging in age from 18 to 21 years, served. They were told they could earn from \$2.00 to \$4.00 per hour depending upon their performance. The subjects had no previous

history of responding on a schedule of reinforcement in an experimental situation.

Apparatus

The experimental chamber was a sound-attenuated room, 3.5 m by 1.75 m. An air-conditioning unit provided ventilation and masked extraneous noises. Control and recording equipment was located in a separate room.

The subject was seated before a console consisting of a metal cabinet, 56 cm wide by 39 cm high, situated on top of a table. The upper panel contained in the center a digital counter with an adjacent red lamp and in the upper left a changeover push button with a green lamp above it. The lower vertical panel contained two Gerbrands rat levers 38 cm apart. A force of approximately 150 g (1.5N) was required to close the switch contacts. Additional stimuli were provided by a blue lamp next to the left lever and a yellow lamp next to the right lever.

Procedure

Two component schedules were programmed concurrently, FI on the left lever and FR on the right lever. Whichever component was available was signaled by the lamp adjacent to the appropriate lever. To change from one component to the other, a response on the changeover button was required. A changeover response resulted in a 5-sec changeover delay (COD) during which all lamps were extinguished, the levers were nonfunctional, and the clock timing the FI stopped. This COD procedure combined with a timeout was adopted on the basis of pilot work in order to decrease the high rate of simple alternation. (Baum, 1975, adopted a changeover response cost procedure to deal with a similar tendency in his human subjects.) At the end of the COD, the green lamp next to the changeover button and the lamp next to the alternative lever were lit, and the program clock resumed timing.

Reinforcement delivery on either component consisted of "points" tallied on the counter and a flash of the red lamp next to the counter. Each point was worth two cents; payment by check for accumulated points was made at approximate biweekly intervals.

Each subject was read verbatim the following instructions before the initial session:

1. Leave watches, books and coats outside booth.
2. Task is to earn points on the counter.
3. Each point is worth \$0.02 (two cents).
4. Earn points by using one or the other of the two switches; not both together.
5. Whichever switch is on is indicated by the light next to it.
6. To change from one switch to the other, press the red button.
7. You may start when the green light goes on.

A brief demonstration of the effects of responding on the changeover button followed the instructions. A typed copy of these instructions was posted on the front of the console throughout the experiment.

Five subjects were trained initially on conc FI 60-sec FR 100, which allowed them to easily complete one or more ratios during a single interval. Seven subjects were trained initially on conc FI 20-sec FR 300, which did not allow the completion of a ratio during a single interval. After achieving a criterion for stable performance, all subjects were shifted to a second schedule: those trained on conc FI 60-sec FR 100 were shifted to conc FI 20-sec FR 300; five of seven subjects trained on conc FI 20-sec FR 300 were shifted to conc FI 60-sec FR 100; the remaining two were shifted to conc FI 60-sec FR 300. Subjects continued on the second schedule until reaching the stability criterion. Table 1 shows the sequence of schedules and the subjects trained on them.

Subjects were trained a minimum of 10 sessions per schedule, and thereafter until stability was reached on both components. The criterion for stable performance was based on overall rate in each component. Over four consecutive sessions, the mean response rate of the first two sessions was compared to that of the

latter two sessions; if these means differed by no more than 10% the criterion was satisfied. In cases in which the criterion was reached on one component before the other, the four criterion sessions for each component had to overlap at least two sessions.

Sessions were 50 min long and were conducted five days a week, usually at the same time each day.

RESULTS

Initial Schedule Performance

Two general response patterns emerged on the initial schedule depending upon the schedule parameters: a) low rate, PRP FI responding in conjunction with high constant rate FR performance, occurring on conc FI 60-sec FR 100; and b) relatively high rate, less accurately timed FI performance in conjunction with few or no FR responses, occurring on conc FI 20-sec FR 300. Figure 1A shows an example of the first pattern, in which the final session performance of DJ is characterized by high FR rates with a brief changeover to the FI component after completion of every four ratios. Figure 1C shows an example of the second pattern, in which the final session performance of MP is characterized by constant FI responding and no responding on the FR component at all.

Conc FI 60-sec FR 100. Four of five subjects (DS, BH, DJ, and SM) spent over 80% of the session time in the FR component responding at high rates, briefly changing over to the FI component after completion of every third or fourth ratio, corresponding to the 1-min interval. One subject (SD) adopted a pattern of alternating response runs on each component. Figure 2A shows that the subjects who responded at high rates on FR made more than 70% of their FI responses in the last quarter of the interval, whereas the one who had an alternation pattern showed a flatter response distribution.

Conc FI 20-sec FR 300. In contrast, six of seven subjects on this schedule spent over 90% of the session time in the FI component, rarely changing over to FR. Four (MP, PO, RL, HS) of these six responded at a high steady rate on FI. The other two, (BU, BM) exhibited PRP FI responding. The seventh subject (PK) alternated between components, making a run of about 40 responses on FR, then changing over to FI and completing the interval. The

Table 1

Sequence of conc FI FR schedules trained for each subject.

Subject	Initial Schedule		Second Schedule	
	FI	FR	FI	FR
DS, BH, DJ, SM, SD	60-sec	100	20-sec	300
MP, PO, BU, RL, PK	20-sec	300	60-sec	100
HS, BM	20-sec	300	60-sec	300

Fig. 1. Cumulative records of the final sessions of subjects on conc FI FR schedules. The initial schedules trained are in Panels A and C; the second schedules in Panels B and D. In each panel the top record is FI, the second record is FR, and the bottom line shows changeover responses. Session length is 50 min; a full vertical excursion of the pen is 500 responses.

distribution of FI responses across each 5-sec quarter of the interval for these subjects is shown in Figure 3A. A flat distribution is seen for those subjects who responded at high FI rates, though with slight increases across the quarters. The two who responded at low FI rates responded primarily in the last quarter. The subject that alternated made all her FI responses in the last two quarters.

Second Schedule Performance

Conc FI 20-sec FR 300. After reaching criterion on conc FI 60-sec FR 100, all subjects were switched to conc FI 20-sec FR 300. All five decreased their FR responding and increased responses, time, and points in the FI component. Three subjects (DS, DJ, SM) continued to respond at high rates in FR, changing over to the FI component every 20 to 30 sec, and then returning to the FR. An example of this performance is given in Figure 1B, which, with

Figure 2B, shows that these subjects continued to display sharp FI temporal discriminations. One subject (BH) responded on the FI component, as she had previously on the FR component, with high constant rates, leading to a flat FI temporal distribution (Fig. 2B). The fifth subject (SD), who previously adopted an alternating pattern, continued to alternate runs between the two components. Thus, these subjects all showed effects of their previous training on conc FI 60-sec FR 100. All five continued to work on the FR component, even though they earned fewer points than if they had simply remained in the FI component. In contrast, six of seven subjects who had conc FI 20-sec FR 300 as their initial schedule tended to ignore the FR component on that schedule. This effect of schedule history is shown graphically by comparing Figures 1B with 1C. Even though the schedules are the same, very different performances are evident.

Fig. 2. Distribution of FI responses across the four quarters of the fixed-interval for individual subjects on conc FI FR schedules. A is the initial schedule trained; B is the second schedule trained. Data were calculated by cumulating the number of responses occurring in each quarter of the FI. Reinforced responses, occurring after the interval elapsed, are counted in the fourth quarter. Data are averages of the four criterion sessions.

Conc FI 60-sec FR 100. After reaching criterion five subjects trained on conc FI 20-sec FR 300 were switched to conc FI 60-sec FR 100 (MP, PO, BU, RL, RK). They all markedly increased their responses, time, and points in the FR component (which on the previous schedule was practically nil) and decreased work in

Fig. 3. Distribution of FI responses across the four quarters of the fixed-interval for individual subjects on conc FI FR schedules. A is the initial schedule trained; B is the second schedule trained. Data are calculated as in Figure 2.

the FI component, thus performing much like those who had been trained initially on that schedule. Three (MP, PO, BU) responded at high rates on FR, changing over to FI after every third point, leading to very sharp temporal patterning on FI (Fig. 3B). An example for subject MP is shown in Figure 1D, which is very similar to the performance of DJ shown

in 1A. One subject (RL) changed over to FI on an irregular basis, and one (PK) who had previously developed an alternation pattern, continued to alternate components.

Conc FI 60-sec FR 300. After reaching criterion two subjects (HS, BM) were switched from conc FI 20-sec FR 300 to conc FI 60-sec FR 300. Both markedly decreased FI responding and increased FR responding. They took about 1 min to complete a ratio, then changed over to FI, resulting in PRP FI performance (Fig. 3B).

Appendix A summarizes the criterion performance for each subject in Experiment 1. Means taken over the four criterion sessions are given because, although the rates were "stable" according to criterion, some daily fluctuations occurred. In general, daily performance was very similar to the mean, but in cases where fluctuations occurred, the use of the mean avoids the problem of presenting a "typical session."

DISCUSSION

In conc FI FR schedules in which it is possible to complete one or more ratios before the interval elapses, subjects typically respond on the FR component at high rates early in the FI period. Changeovers to the FI component typically occur after the delivery of an FR reinforcer. Responses on the FI component occur late in the interval or after it has elapsed, leading to good temporally discriminated FI performance. This general pattern has been noted for rats (Skinner & Morse, 1957), pigeons (Catania, 1966; LaBounty & Reynolds, 1973) and humans (Poppen, 1972; Sanders, 1969) as well as in the present study. Further, the present study shows this pattern appears even when another pattern has been established by a previous reinforcement schedule.

When parameters are such that it is not possible to complete at least one ratio during the period of an FI, performance is considerably more varied, as shown in the present study and in LaBounty and Reynolds (1973). Subjects trained initially on conc FI 20-sec FR 300 responded on FI with high or low rates but generally ignored the FR component. It was anticipated that subjects could discriminate the passage of time on the FI by responding on the FR and at the same time make progress toward completing the ratio. No one (without a conc FI 60-sec FR 100 history) adopted this pattern.

One reason may be that the 10 sec that would have been lost for each changeover to FI and back again would reduce FI reinforcement totals below what could be made up by responding on FR. It was more efficient to ignore the FR. It is not known if subjects would "time" the FI by responding on the FR if it were less costly to do so.

Since different general patterns of response were produced by the two sets of schedule values initially trained, it was possible to determine the persistence of the patterns when the schedule values were changed. Responding on conc FI 60-sec FR 100 influenced performance on subsequent conc FI 20-sec FR 300. All five subjects with a history on the former schedule responded more on the FR component of the latter schedule than five of six persons initially trained on conc FI 20-sec 300. Some apparently did discriminate the FI by making a regular number of ratio responses (e.g., Figure 1B).

On the other hand, a history of responding on conc FI 20-sec FR 300 seemed to have no effect on subsequent performance on conc FI 60-sec FR 100. The controlling factor for the response pattern on conc FI 60-sec FR 100 seems to be the discriminative function FR point delivery has for changing over to FI. Most subjects in the present study, and in the Poppen (1972) study, adopted the pattern of completing three FRs and then changing over to FI, regardless of their previous schedule history.

An alternative pattern, adopted by a minority of subjects regardless of schedule values, was to alternate response runs on each component.

In summary, Experiment 1 demonstrated that the pattern of performance on FI in a conc FI FR situation is a function of the parameter values of the schedule components, specifically whether or not the fixed-ratio can be run off in a time period shorter than the interval. Experiment 1 also demonstrated that history effects may occur in complex schedules, again as a function of parameter values of the components.

EXPERIMENT 2

HUMAN PERFORMANCE ON CONCURRENT FI DRL SCHEDULES

Poppen (1972) found that human subjects typically responded at high constant rates on a FI 60-sec schedule when a DRL 20-sec schedule

was concurrently programmed. Although the DRL value was one-third the FI value, subjects typically remained in the FI component, changing over to the DRL component and back again three times each interval, even though this pattern unnecessarily increased COD's and decreased the frequency of reinforcement. Making a specific number of responses on the FI lever in each 20-sec period seemed to aid discrimination of the DRL time requirement. Experiment 2 investigated further interactions between performance on concurrent FI and DRL schedules by varying the temporal parameter of the schedules, i.e., under conditions where the FI was longer than, equal to, or shorter than the DRL interval. Also, after stable performances were obtained, the temporal parameters were changed to assess the persistence of response patterns under the new schedule conditions.

METHOD

Subjects

Nine female and five male university students, aged 18 to 23 years, served. Other conditions were identical to Experiment 1.

Apparatus

The experimental chamber and response console were the same as in Experiment 1.

Procedure

Two component schedules were programmed concurrently, FI on the left lever and DRL on the right lever. All other conditions and instructions were identical to Experiment 1.

Time parameter values of the FI and DRL components were selected so that the size of the DRL requirement covered a wide range, both greater and less than the FI value. Table 2 shows the schedule values and the order in

which they were studied. As in Experiment 1, subjects were trained a minimum of 10 sessions, with additional sessions conducted as needed to reach the criterion of stable performance. Subjects were then trained to criterion on a second schedule. Four subjects who showed very strong schedule history effects were trained on a third schedule to test the limits of history control.

RESULTS

Initial Schedule Performance

Considering the initial schedule on which the subjects were trained, several general findings emerged. Good DRL control occurred for 11 of 14 subjects for all schedule parameters. Most responded once per DRL period; one subject (PC) responded with a burst, one (LH) made occasional high rate runs, and one (WL) responded at a high rate for one minute after each DRL point. Two general patterns of response distribution within the FI emerged: constant responding throughout the interval or a few responses at the end of the interval (PRP). These patterns were related, to some extent, to the temporal values of the schedule components, though individual subject differences were also important. Performance on each schedule is described below.

Conc FI 100-sec DRL 10-sec or 20-sec. These subjects remained almost exclusively in the DRL component. One (TL), who started with DRL 10-sec, ceased responding in FI altogether. The two subjects (SA, JL) started with DRL 20-sec remained in the DRL component, changing over briefly to FI at intervals greater than 100 sec, resulting in the PRP FI pattern. An example is shown in the final session of Subject SA shown in Figure 4A. The most efficient performance would have been to change over to FI after every five DRL points, but

Table 2
Sequence of *conc FI* DRL Schedules Trained for Each Subject

Subject	Initial Schedule		Second Schedule		Third Schedule	
	FI (sec)	DRL (sec)	FI (sec)	DRL (sec)	FI (sec)	DRL (sec)
JL	100	20	60	20		
SA	100	20	60	20	20	100
TL	100	10	60	20	20	100
RS, VM	60	20	100	20	100	10
LH, BR	60	20	20	100		
RR, MB, SS	60	60	60	20		
WL, PC, SM, JG	20	100	60	20

Fig. 4. Cumulative records of the final sessions of subjects on conc FI DRL schedules. The initial schedules trained are in Panels A and C; the second schedules in Panels B and D. In each panel the top record is FI, the second record is DRL, and the bottom line shows changeover responses. Session length is 50 min; a full vertical excursion of the pen is 500 responses.

neither subject adopted this pattern consistently. Their distribution of FI responses over the 25-sec quarters is shown in Figure 5A.

Conc FI 60-sec DRL 20-sec. These subjects remained in the FI component responding at a steady pace, changing over briefly to DRL approximately three times per interval. Each subject responded a consistent number of times on FI before changing over to DRL. Examples of final performances on this schedule are shown in Figures 4C and 9C. Three subjects changed over to DRL regardless of where they were in the interval, leading to constant FI response patterns, whereas the fourth (VM) changed over at exactly the same times within each interval, leading to a bimodal FI response distribution. Response distributions within the interval are shown in Figure 6A.

Conc FI 60-sec DRL 60-sec. These subjects remained in the FI component, changing over

briefly to DRL at the completion of each FI point. Two subjects (RR, MB) responded with constant FI rates and one (SS) responded with the PRP FI pattern. An example of the constant pattern is shown for Subject MB in Figure 7A. The distribution of FI responses for these subjects is shown in Figure 8A.

Conc FI 20-sec DRL 100-sec. These subjects remained in the FI component, changing over to DRL after every six FI points. Two subjects (WL, PC) responded with the constant FI pattern and two (SM, JG) with the PRP FI pattern. An example of the PRP pattern is shown for Subject SM in Figure 9A. The distribution of FI responses for these subjects is shown in Figure 10A.

Subsequent Schedule Performance

Turning to the second schedules on which subjects were trained, strong history effects are

Fig. 5. Distribution of FI responses across the four quarters of the fixed-interval for individual subjects on conc FI DRL schedules. A is the initial schedule trained; B is the second schedule trained. Data are calculated as in Figure 2.

apparent. In general, subjects tended to persist in whatever FI pattern, constant or PRP, that they had developed in the initial schedule. Figures 5B, 6B, 8B, and 10B show the distribution of responses across quarters of the FI on the second schedule. These patterns are generally similar to those of the same subject on the initial schedule. Also, the pattern of changeovers between components set up under the initial schedule tended to persist when the schedule values were changed. Performance on each schedule, related to the initial schedule trained, is described below.

Conc FI 60-sec DRL 20-sec. Subjects SA, JL, and TL (trained initially on conc FI 100-sec DRL 20 or 10-sec) responded very differently from subjects initially trained on this schedule. They continued to remain in the DRL component with brief changeovers to FI, resulting in low rate temporally discriminated FI performance. Subject JL did not alter his performance at all and did not contact the

Fig. 6. Distribution of FI responses across the four quarters of the fixed-interval for individual subjects on conc FI DRL schedules. A is the initial schedule trained; B is the second schedule trained. Data are calculated as in Figure 2.

changed contingencies, whereas SA and TL did develop an efficient pattern of changing over to the FI component after every three DRL points. An example is shown for Subject SA in Figure 4B; her performance is similar to that of her initial schedule (Figure 4A) and differs markedly from subjects started on conc FI 60-sec DRL 20-sec (Figure 4C and Figure 9C). Figure 5B shows the distributions of FI responses for these subjects on this schedule; again performance differs from that of subjects started on this schedule (Figure 6A).

Subjects RR, MB, and SS (trained initially on conc 60-sec DRL 60-sec) displayed a very

Fig. 7. Cumulative records of the final sessions of a subject on conc FI DRL schedules. The initial schedule trained is in Panel A; the second schedule in Panel B. In each panel the top record is FI, the second record is DRL, and the bottom line shows changeover responses. Session length is 50 min; a full vertical excursion of the pen is 500 responses.

different pattern. Two (RR, MB) remained in the FI component, responding at high rates, changing over to DRL after every FI point.

Thus, they continued to respond as they had on their initial schedule and did not contact the changed contingencies. An example is shown in Figure 7B, which is highly similar to that in Figure 7A but differs from Figures 4C and 9C. One (SS) changed to a pattern of alternating between components at 20-sec intervals.

Performance on conc FI 60-sec DRL 20-sec varied for subjects who were trained initially on conc FI 20-sec DRL 100-sec. Two (PC, SM) developed a pattern similar to those trained initially on this schedule. An example is given in Figure 9B, which is comparable to Figures 4C and 9C. One (WL), for whom good DRL control had not been achieved, developed an alternation pattern; and one (JG), who had achieved very good FI temporal discrimination, developed a pattern in which she remained in the DRL component, changing over to FI after every 3 DRL points.

Conc FI 20-sec DRL 100-sec. The performance of subjects with a history of other schedules was similar to that of subjects trained initially on this schedule. Subjects LH and BR (trained initially on conc FI 60-sec DRL 20-sec) continued to respond at high rates in FI, changing over to the DRL component after every seven FI points. An example is shown in Figure 9D, which is similar to Figure 9A in terms of time allocation between the two components, even though the FI pattern differed. Subjects SA and TL (trained first on conc FI 100-sec DRL 20 or 10-sec, and then on conc FI

Fig. 8. Distribution of FI responses across the four quarters of the fixed-interval for individual subjects on conc FI DRL schedules. A is the initial schedule trained; B is the second schedule trained. Data are calculated as in Figure 2.

Fig. 9. Cumulative records of the final sessions of subjects on conc FI DRL schedules. The initial schedules trained are in Panels A and C; the second schedules in Panels B and D. In each panel the top record is FI, the second record is DRL, and the bottom line shows changeover responses. Session length is 50 min; a full vertical excursion of the pen is 500 responses.

60-sec DRL 20-sec) finally altered their pattern to one of remaining in the FI component, responding at high rates and changing over to DRL after every five FI points.

Conc FI 100-sec DRL 20-sec. Subjects RS and VM (trained initially on conc FI 60-sec DRL 20-sec) continued to respond at a steady pace in the FI component, changing over to the DRL component every 20-sec. This is shown in Figure 4D for Subject RS. This performance is markedly different from that of Subjects (SA, JL) trained initially on this schedule. Compare Figure 4A with Figure 4D. When the DRL value was further decreased to 10-sec, RS and VM continued to respond in the same fashion, changing over briefly to DRL at about 10-sec intervals.

Appendix B summarizes the mean criterion performance for each subject in Experiment 2.

DISCUSSION

Performance on conc FI 60-sec DRL 20-sec replicated previous findings for this schedule (Poppen, 1972). Subjects remained in the FI component, responding at a steady rate, changing over to the DRL component about three times per interval. They appeared to "pace" the DRL by responding on FI, in much the same way that Bruner and Revusky's (1961) subjects responded on nonfunctional keys when spacing DRL responses. This strategy resulted in less than the maximum frequency of reinforcement that could be earned. When the parameters were such that this strategy was even more costly, as in conc FI 100-sec DRL 20 or 10-sec, subjects performed differently. They remained in the DRL component, changing over to FI briefly, or in the case of the DRL

Fig. 10. Distribution of FI responses across the four quarters of the fixed-interval for individual subjects on conc FI DRL schedules. A is the initial schedule trained; B is the second schedule trained. Data are calculated as in Figure 2.

10-sec, not at all. Thus when contingencies were strong enough, subjects did not pace DRL responding on the FI but spaced DRL responses in some other (unspecified) manner.

The above patterns held true only for the initial schedule on which subjects were trained. Once a pattern was established, it persisted when a schedule was implemented which produced a different pattern if presented first. Thus, subjects who learned to remain in the DRL component continued to do so when the schedule was changed to conc FI 60-sec DRL 20-sec. (They did, however, break out of this pattern when the schedule was further changed to conc FI 20-sec DRL 100-sec). And subjects who learned to pace their DRL re-

sponding on FI continued to do so when the schedule was changed to conc FI 100-sec DRL 20-sec, and even when the DRL was further reduced to 10-sec. For these subjects, their schedule history led to very inefficient performance.

When the FI was equal to or less than the DRL component, subjects remained in the FI component. Since delivery of FI points was discriminative for changing over to DRL under these conditions, there was no consequence for a particular pattern of FI responding. Thus, both high and low rate FI performance occurred. History effects were also apparent for these subjects. Those trained under conc FI 60-sec DRL 60-sec continued to show an alternation pattern when changed to conc FI 60-sec DRL 20-sec. Two, who had responded at high FI rates, continued to change over to DRL after every FI point and thus never contacted the changed contingencies. One, who responded at low FI rates, did change so that she alternated between components at 20-sec intervals. Subjects trained on conc FI 20-sec DRL 100-sec developed a variety of patterns when switched to conc FI 60-sec DRL 20-sec, no one of which characterized the group.

GENERAL DISCUSSION

The results of the present study affirm the notion that human performance on FI schedules is determined, in part, by what else there is to do in the situation, that is, by concurrent schedules. As Catania (1966) noted, the single operant is a special case, inasmuch as most behavior occurs in a context of multiple contingencies. Even in a single operant situation other contingencies abound, although they are left unspecified and unobserved.

The various FI response patterns, constant or with postreinforcement pause, which have been reported in some studies of the single operant (e.g., Weiner, 1969) may result from idiosyncratic interim activities. Examples from other studies in our laboratory include one subject on a FI 80-sec schedule who was able to verbally describe the contingency perfectly, yet who "counted" the interval by responding once per second, resulting in a constant pattern (Duvinsky & Poppen, 1982). Another subject systematically wandered around the experimental chamber, returning to the console once per minute to make a reinforced re-

sponse, resulting in a postreinforcement pause. The present experiment, by explicitly programming concurrent contingencies, was able to show how FI performance is affected. These data are consistent with other studies which have shown that temporally discriminated performance is affected by manipulating opportunities for concurrent behavior (Glazer & Singh, 1971; Laties & Weiss, 1963; Poppen, 1972). Specifically, when responding on the FR or DRL component was strongly reinforced, as in conc FI 60-sec FR 100 or conc FI 100-sec DRL 20-sec, the PRP FI pattern ensued. When FI responding possibly helped to discriminate the DRL period, constant rates occurred (i.e., on conc FI 60-sec DRL 20-sec). When the contingencies were such that subjects remained in the FI component with no particular advantage for responding at high or low rates, both patterns occurred (i.e., on conc FI 20-sec FR 300, conc FI 60-sec DRL 60-sec, and conc FI 20-sec DRL 100-sec).

This study also extended the role of reinforcement history, an important determinant of human FI performance in the single operant (Weiner, 1964, 1969), to concurrent schedules. Not only did the FI response pattern itself tend to persist, but also the overall pattern of alternating between the components of the concurrent schedule. It is easy to understand the persistence of a pattern when it results in equal or increased amounts of reinforcement under the new contingencies (examples are conc FI 100-sec DRL 10 or 20-sec changed to conc FI 60-sec DRL 20-sec, and conc FI 60-sec DRL 60-sec changed to conc FI 60-sec DRL 20-sec). It is also clear why a response pattern would change so as to maximize reinforcement under the changed contingencies (examples are conc FI 20-sec FR 300 changed to conc FI 60-sec FR 100 or to conc FI 60-sec FR 300, and Subjects SA and TL when changed from conc FI 60-sec DRL 20-sec to conc FI 20-sec DRL 100-sec). But the persistence of a response pattern that leads to decreased and less than maximal reinforcement is difficult to account for (examples are conc FI 60-sec FR 100 changed to conc FI 20-sec FR 300, and conc FI 60-sec DRL 20-sec changed to conc FI 100-sec DRL 20-sec and 10-sec). One possible explanation is that human subjects generate "rules" (Lowe, 1979; Skinner, 1969), verbal statements of response strategies, which continue to govern their behavior when the contingencies change.

Kaufman, Baron, & Kopp (1966) have shown that experimenter-given instructions can supersede schedule control in humans. Several studies have demonstrated the relationship between human FI performance, experimenter instructions, and subjects' own statements of the contingencies (Duvinsky & Poppen, 1982; Harzem, Lowe & Bagshaw, 1978; Lippman & Meyer, 1967). It is likely that humans can produce their own instructions and continue to follow them even when conditions change such that other modes of behavior would be more efficient (Luchins, 1942). The conditions responsible for the generation of rules which control behavior, whether efficiently or inefficiently, remain to be explored.

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Received February 27, 1981

Final acceptance October 2, 1981

APPENDIX A

Order of schedules; number of sessions; number of responses, time in min, and number of points earned in each component; and number of changeovers; for subjects trained on conc FI FR schedules. Data are averages for four criterion sessions. Responses, points, and CO's are rounded to nearest whole number.

Subject	Schedule		No. Sess.	FI		FI Points	FR		FR Points	No. CO's
	FI	FR		Resp.	Time		Resp.	Time		
DS	60	100	19	424	1.89	43	13,016	41.13	130	99
	20	300	12	616	4.44	147	7,899	26.69	26	290
BH	60	100	18	106	0.84	41	13,517	44.40	135	86
	20	300	10	14,406	42.32	135	1,766	5.47	6	30
DJ	60	100	17	64	1.00	42	17,067	43.07	171	87
	20	300	14	235	1.44	95	14,256	34.70	47	194
SM	60	100	14	60	0.68	42	12,699	43.25	126	83
	20	300	10	158	1.56	95	9,398	35.14	31	193
SD	60	100	14	2,078	17.34	43	4,061	25.27	40	105
	20	300	22	3,761	25.20	135	2,637	15.28	8	151
MP	20	300	19	3,342	50.00	155	0	0	0	0
	60	100	13	52	0.90	39	13,556	43.34	135	82
PO	20	300	28	12,306	48.49	148	165	0.52	1	4
	60	100	11	133	1.11	42	14,733	42.82	147	86
BU	20	300	16	843	49.00	137	57	0.70	0	3
	60	100	13	87	0.72	42	14,250	43.60	143	88
RL	20	300	11	2,855	45.94	140	10	0.20	0	3
	60	100	22	67	0.77	9	11,132	47.80	111	21
PK	20	300	15	6,134	17.04	110	4,724	16.99	15	223
	60	100	10	5,350	14.31	39	8,012	24.33	80	152
HS	20	300	12	4,518	49.88	150	14	0.05	0	1
	60	300	10	319	3.77	36	9,967	40.49	31	83
BM	20	300	10	944	45.43	129	429	2.26	2	15
	60	300	14	261	2.97	36	9,595	40.42	32	79

APPENDIX B

Order of schedules; number of sessions; number of responses, time in min, and number of points earned in each component; and number of changeovers; for subjects trained on conc FI DRL schedules. Data are averages for four criterion sessions. Responses, points, and CO's are rounded to nearest whole number.

<i>Subject</i>	<i>Schedule</i>		<i>No.</i>	<i>FI</i>	<i>FI</i>	<i>FI</i>	<i>DRL</i>	<i>DRL</i>	<i>DRL</i>	<i>No.</i>
	<i>FI</i>	<i>DRL</i>	<i>Sess.</i>	<i>Resp.</i>	<i>Time</i>	<i>Points</i>	<i>Resp.</i>	<i>Time</i>	<i>Points</i>	<i>CO's</i>
SA	100	20	10	21	1.28	15	242	46.22	102	34
	60	20	10	38	6.08	32	127	39.10	115	69
	20	100	19	9,559	45.90	143	28	0.24	26	57
JL	100	20	11	14	0.27	12	126	48.55	122	26
	60	20	10	13	0.21	13	128	48.06	116	26
TL	100	10	10	2	0.03	0	267	50.00	253	1
	60	20	10	38	0.44	35	124	44.23	108	74
	20	100	16	769	45.90	132	32	0.48	24	51
RS	60	20	10	528	28.35	35	107	6.30	100	212
	100	20	10	516	28.84	21	105	2.10	97	207
	100	10	10	800	20.23	17	159	6.48	156	318
VM	60	20	10	143	26.02	44	135	4.94	126	268
	100	20	10	136	33.53	21	94	3.13	84	187
	100	10	10	146	26.10	19	138	4.25	137	275
LH	60	20	31	4,191	34.20	39	340	3.54	83	173
	20	100	10	4,883	41.73	143	619	5.09	17	42
BR	60	20	21	10,469	33.33	39	103	1.89	92	205
	20	100	10	12,709	47.75	147	16	0.24	16	32
RR	60	60	29	6,316	41.75	45	51	1.39	44	89
	60	20	10	4,440	41.43	46	58	1.56	46	103
MB	60	60	24	2,635	43.05	44	51	0.65	34	90
	60	20	10	2,747	44.21	46	48	0.51	46	94
SS	60	60	36	187	39.41	43	49	7.74	38	89
	60	20	10	101	18.63	33	103	16.92	94	202
WL	20	100	11	8,963	37.52	136	2,909	9.23	21	46
	60	20	10	12,813	39.29	46	64	0.85	46	93
PC	20	100	18	7,654	46.62	144	61	0.64	21	47
	60	20	19	4,141	32.49	38	436	4.23	86	193
SM	20	100	14	756	46.31	139	24	0.35	23	47
	60	20	34	826	34.72	37	113	1.71	85	190
JG	20	100	10	304	47.56	133	23	0.48	21	44
	60	20	10	37	0.64	37	116	44.35	113	51