EFFECTS OF CONCURRENT SCHEDULES ON HUMAN FIXED-INTERVAL PERFORMANCE¹

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Young adults performed a lever-pressing task for money on two schedules of reinforcement: concurrent fixed-interval 1 min—differential-reinforcement-of-low-rate 20-sec, and concurrent fixed-interval 1-min—fixed ratio 100 responses. All subjects were trained on both schedules. Fixed-interval performance concurrent with the differential reinforcement procedure was characterized by high constant rates with no post-reinforcement pauses. Fixed-interval performance concurrent with fixed ratio was characterized by low rates and lengthy post-reinforcement pauses. These results differ from those obtained in prior studies on the effects of conditioning history upon subsequent fixed-interval performance. The prior work, using non-concurrent procedures, had shown that fixed-interval performance following differential reinforcement of low rates was characterized by post-reinforcement pauses and low rates, while fixed-interval performance following fixed ratio exhibited high constant rates and no post-reinforcement pause. The present results suggest that alternative concurrent contingencies are another major determinant of human fixed-interval performance.

Performance of human subjects on fixed-interval (FI) schedules of reinforcement typically falls into one of two categories (Weiner, 1969). Response rate may be relatively high with no pauses after reinforcement, or response rate may be low with a pause after each reinforcement for all or part of the succeeding interval. Several variables have been found to affect the FI response pattern, including instructions (Azrin, 1958; Lippman and Meyer, 1967), response effortfulness (Azrin, 1958), a discriminative stimulus preceding reinforcement availability (Azrin, 1958), response cost or point loss per response (Weiner, 1962), and conditioning history (Weiner, 1964).

Conditioning history, or experience on other schedules of reinforcement, has received the most extensive systematic investigation of any of the above variables. Weiner (1964; 1969) showed that training on a differential-reinforcement-of-low-rate (DRL) schedule results in post-reinforcement pauses and low rates in subsequent FI schedules, while train-

ing on a fixed-ratio (FR) schedule results in high constant rates with no pauses in subsequent FI schedules. Weiner has demonstrated also that the conditioning history does not have to occur before performance on FI. Fixed-ratio and DRL schedules exert their effects when alternated with mixed fixed-interval schedules (Weiner, 1972).

The effects of conditioning histories are most obvious when the response pattern is first established by the FR or DRL schedule and then maintained on a subsequent FI. But the occurrence of history effects in mixed FI FR and mixed FI DRL schedules (Weiner, 1972) shows that the serial order is not necessary; history effects occur when the schedules are presented nearly simultaneously. Can we carry these findings one step further, and establish history effects when the schedules are arranged concurrently?

An experiment by Frazier and Bitetto (1969) provides some evidence for history effects in a concurrent schedules situation, employing FI, DRL and variable-interval (VI) schedules. They reported that most subjects on concurrent (*conc*) FI VI DRL schedules displayed a DRL pattern of responding in each of the three components, with no difference in rate among the components. Several subjects placed on *conc* FI FR DRL schedules showed appropriate differential schedule control; that

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is, high constant rates of responding on FR, low rates on DRL, and response acceleration within the interreinforcement interval on FI. Thus, in the first instance, DRL tended to determine interval performance. The substitution of FR for VI had some effect in increasing the rate of responding on FI. However, there was wide intersubject variability in this study, suggesting that factors other than the schedule were important in determining the final behavior.

Sanders (1969) obtained low rates of responding on FI from subjects working on *conc* FI FR schedules. These data are contrary to a simple extension of the principle that experience on FR results in high constant FI rates. However, a possible reason for the low rates in the Sanders study is that his subjects had previous experience with DRL schedules. As Weiner (1969) showed, a DRL history results in low FI rates even if experience with FR intervenes between the DRL and FI.

Laties and Weiss (1963) investigated the effects of a concurrent subtraction task on FI performance. Subjects were trained to press a key that illuminated a meter dial on which pointer deflections occurred on a fixed interval. Temporal discrimination was facilitated by a heavy force requirement on the key and by instructing the subjects about the frequency and duration of the pointer deflections. The addition of a concurrent arithmetic subtraction task made response rate more constant throughout the interval. The results were explained in terms of the disruption of the subjects' counting behavior, which mediated their FI performance.

The above studies indicate that concurrent schedules have an effect on FI performance, though typically too many variables have been involved to permit a clear conclusion. The purpose of the present experiment was to explore further the effects of concurrent contingencies on human FI behavior. Are certain concurrent schedules responsible for high rate FI performance and others responsible for low FI rates? Specifically, can the "history effects" of FR and DRL be established in a concurrent situation?

METHOD

Subjects

Four males and three females ranging from 18 to 24 yr of age were hired from the student

population of Southern Illinois University. 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 approximately 3.5 m by 1.75 m with indirect lighting provided by six 75-w lamps. A 5000-BTU air conditioning unit was on continuously during each session to provide ventilation and mask extraneous noises. Scheduling of points and recording of responses were accomplished with solid-state equipment (BRS-Foringer) located in a separate room.

The subject was seated before a console consisting of a metal cabinet, 22 in. wide by 15 in. high (56 by 38 cm), situated on top of a table. The upper part of the console sloped away from the subject at a 30° angle. The upper panel contained in the center a digital counter with an adjacent red reinforcement indicator lamp, and in the upper left a red changeover push button with a green "start" lamp above it. The lower vertical panel contained two toggle switches 15 in. (38 cm) apart. A force of approximately 150 g (1.5 N) was required to close the switch contacts. Discriminative stimuli were provided by a blue lamp next to the left switch, on which FI was scheduled, and a yellow lamp next to the right switch, on which FR or DRL was scheduled.

Procedure

Two concurrent schedules were employed: a concurrent fixed-interval 1-minute-differential-reinforcement-of-low-rate 20-sec (*conc* FI DRL) and a concurrent fixed-interval 1-minute-fixed-ratio 100 response (*conc* FI FR). In both schedules, a response on the changeover button was necessary to switch from one component to the other. A changeover response resulted in a 3-sec changeover delay (COD) during which all lamps were extinguished and the keys were non-functional. The COD was imposed to avoid the occurrence of accidental chaining. During the COD, the clocks timing the FI and the DRL stopped.

Four subjects were started on the *conc* FI DRL schedule and three were started on the *conc* FI FR schedule. After reaching a cri-

terion of stable performance in both components of the initial schedule, each subject was then exposed to the alternative schedule; *i.e.*, those on the *conc* FI DRL were switched to *conc* FI FR and those started on the *conc* FI FR were switched to the *conc* FI DRL. The stability criterion was derived from Schoenfeld, Cumming, and Hearst (1956). Over four consecutive sessions, the mean of the first two sessions was compared with the mean of the second two. If the difference between these two submeans was no greater than 5% of the grand mean for the four days, the criterion of stability was considered to have been met. The same criterion was required in the second phase as well. One subject terminated the study before reaching criterion on the second phase. His data are not included.

Each subject was read 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 simultaneously.
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

Fig. 1. Responses per minute in each component of *conc* FI 1-min DRL 20-sec and *conc* FI 1-min FR 100.

the instructions. A typed copy of these instructions was posted on the front of the display panel throughout the experiment.

Experimental sessions were 50 min in duration. Subjects had from three to five sessions per week. Payment for points earned was delivered in a lump sum about midway through the study and the remainder at the end. The purpose of the experiment was explained and questions answered as each subject completed the experiment.

RESULTS

The daily response rate in each component, calculated by dividing the number of responses on each key by the 50-min session length, is presented in Figure 1 for each subject. Subjects A, B, and C had *conc* FI DRL in the first phase and after reaching the sta-

bility criterion were changed to *conc* FI FR. Subjects D, E, and F started on *conc* FI FR and were changed to *conc* FI DRL.

The proportion of total FI responses that occurred in each 15-sec quarter of the 60-sec intervals was determined for each session. Responses occurring after the 60-sec interval had elapsed were counted in the fourth quarter. The mean proportions of responses in each FI quarter for the four criterion sessions in each phase are presented in Figure 2. Subjects are labelled as in Figure 1.

FI performance during conc FI DRL. Fixed-interval responding in *conc* FI DRL was characterized by high constant rates. As shown in Figure 1, FI rate in this schedule was higher than FI rate in *conc* FI FR in all but one instance. Figure 2 shows that in four of six instances, FI responding was constant throughout the interval. That is, 25% of the responses

Fig. 2. Mean proportion of FI responses occurring in each 15-sec quarter of the 1-min interval for the four criterion sessions.

occurred in each quarter of the FI for Subjects A, B, C, and D. (The subject who terminated early also showed this pattern.) Five of six subjects spent about 80% of the session time in the FI component during *conc* FI DRL. All subjects spent more time in FI during this schedule than during *conc* FI FR, as shown in Figure 3.

An example of *conc* FI DRL performance is shown in the cumulative records in Figure 4. Subjects tended to make a fairly constant number of responses on the FI key in each 20-sec DRL interval. The subject then changed over to the DRL key, obtained the point, and returned to the FI component. The changeover to DRL and back is shown as a pause in the FI record (e.g., at point *a*, Figure 4). As shown by the pauses in Figure 4, these changeovers occurred at approximately 20-sec intervals and were not systematically related to FI reinforcement. Most subjects displayed no post-rein-

forcement pause in FI and no response acceleration toward the end of the interval. Fixed-interval responding served to pace DRL performance.

Two subjects showed a different pattern of responding. In the case of Subject E, DRL control was never achieved. Although three DRL points were available for every one on FI, she persisted in alternating between the two components. After receiving a DRL point, she continued to respond on DRL at a high rate for over 30 sec. She would then change over to the FI component and respond at a high rate until the FI reinforcement, at which point she would change over to DRL, and repeat the cycle. Thus, her rate of responding on DRL was slightly higher than on FI (Figure 1 E), and she spent more than 50% of the time in the DRL component (Figure 3 E). This mode of responding gave rise to the appearance of the FI scallop in Figure 2 E.

Fig. 3. Proportion of session time spent in the FI component during *conc* FI 1-min DRL 20-sec and *conc* FI 1-min FR 100.

Fig. 4. Cumulative record of Subject D during criterion performance on *conc* FI 1-min DRL 20-sec.

Subject F also showed FI scalloping. Like most other subjects, he responded at a high constant rate in FI during the early sessions on the *conc* FI DRL. But before reaching the stability criterion in both components, he began pausing on FI. In one session, his rate of responding on FI dropped precipitously (Session 19, Figure 1 F) and stayed at this low value until criterion was reached. Subject F frequently paused after FI reinforcement, with accelerated responding toward the end of the interval (Figure 2 F). Performance on DRL was very accurate, with changeovers to the DRL component at very close to 20-sec intervals.

Subject B occasionally responded at a low rate on FI within a single session (e.g., Session 13, Figure 1 B). But her terminal performance was characterized by steady rates throughout the interval.

FI performance in *conc* FI FR. In contrast to the previous schedule, FI performance in *conc* FI FR was characterized by low rates and post-reinforcement pauses. In all cases, FI re-

sponse rates were lower in this schedule than were the FI response rates in *conc* FI DRL (Figure 1). Figure 2 shows that the greatest proportion of FI responses was made in the final quarter of the interval. In fact, most FI responses occurred after the 60-sec interval had elapsed. A typical response pattern is shown in Figure 5. In this case, the subject responded on FR at high rates until three points had been obtained. This took slightly longer than 60 sec. The subject would then change over to FI, pick up the point, and switch back to the FR component. Note that all changeovers to the FI occurred after an FR reinforcement, leading to a post-reinforcement pause on every third reinforcement (e.g., point a, Figure 5). In contrast to *conc* FI DRL, most subjects spent less than 10% of the time in the FI component on *conc* FI FR (Figure 3).

An exception to the above pattern again occurred with Subject E. She alternated between the two components, changing over to FI after every FR point instead of every second, third, or fourth FR point, as did the other subjects.

Fig. 5. Cumulative record of Subject D during criterion performance on *conc* FI 1-min FR 100.

This resulted in the bulk of her FI responses occurring in the middle of the interval (Figure 2 E). This pattern also accounted for the higher rate of FI responding (Figure 1 E) and the greater proportion of time spent in the FI component (Figure 3 E) relative to the other subjects on *conc* FI FR.

DISCUSSION

Four of five subjects who exhibited DRL stimulus control on *conc* FI DRL also displayed high constant rates of FI responding. Subjects on *conc* FI FR displayed temporally spaced low rates of FI responding. These data are just the opposite of what would be expected from a simple extrapolation to the concurrent situation of Weiner's studies of history effects on the single operant.

Previous research has shown that variables that have slight or negligible effects on a single operant have more pronounced effects in a concurrent situation. Experiments with hospitalized mental patients have shown that punishment, in the form of timeout or noise, has little suppressive effect on a single operant, but produces almost complete suppres-

sion when an alternative non-punished response is provided (Holz, Azrin, and Ayllon, 1963; Herman and Azrin, 1964). Similarly, studies of reinforcement magnitude in rats and pigeons have shown little effect on a single operant rate, but strong effects in concurrent choice situations (see discussion by Neuringer, 1967). However, the opposite effects of a variable in the concurrent situation as compared to the single operant have not been previously reported.

Weiner (1970) developed the notion of a "one-behavior organism" to explain history effects in the single operant situation. Such an organism is one that has only a single mode of response, established by experience on either an FR or DRL schedule, and that persists in that pattern of response as long as there is any pay-off, however minimal. Thus, FR or DRL response patterns are maintained on an FI schedule, which provides some reinforcement for a wide range of rates. In order to perform adequately on altered contingencies, Weiner suggests that alternative behaviors must be established in the organism's repertoire.

We may extend Weiner's notion of a "one-behavior organism" to include a "one-

behavior situation". Just as FI performance is determined by alternative behaviors in the organism's repertoire, FI performance is also determined by alternative contingencies available in the environment. As Catania (1966) pointed out, the single operant is a special case. To analyze behavior adequately, we must consider the instances in which two or more operants are appropriate.

The notion of a "two-behavior situation" may be useful when considering post-reinforcement pauses. One often notes that a rat or pigeon engages in some other behavior, such as grooming or circling, during a post-reinforcement pause. Similarly, in the present experiment, the subject was typically engaged in some other behavior, namely responding on the alternative schedule, during the post-reinforcement pause. He responded on FI during the post-reinforcement pause in FR or DRL and responded on FR during the post-reinforcement pause in FI. Interestingly, when responding on the alternative schedule was discouraged, as with DRL, FI post-reinforcement pauses did not occur in most cases. This raises the question of whether the post-reinforcement pauses in FI were due to the high response rate requirement on the alternative FR schedule, or whether such pauses would occur with any alternative schedule that did not punish high rates of responding. If the latter were the case, one would expect FI post-reinforcement pauses in *conc* FI VI or *conc* FI FI schedules. Post-reinforcement pauses would not be expected when the alternative schedule involved cost or punishment, for example in *conc* FI VI cost.

There are two instances of somewhat anomalous data in the present study. Subject E persisted in switching to FI after every FR point. This resulted in reinforcement for every second FI response run, which was enough to maintain this alternating behavior. Sanders (1969) reported that both his subjects made a brief response run on FI following each FR reinforcement, but only Subject E displayed this behavior in the present study. When changed to *conc* FI DRL, she continued to alternate between the two components with a high-rate run following each DRL point before changeover to FI. After the experiment, the subject verbalized a complex ratio strategy indicating a superstitious chaining between the two components. This is perhaps an exam-

ple of FR history control of not only FI but DRL performance. Subject F was the only person during *conc* FI DRL to show FI post-reinforcement pauses while remaining in the FI component. His performance was more like a "true" FI scallop in that he did not respond on the alternative schedule during the post-reinforcement pause. His low rate FI performance may be an example of a history effect of concurrent DRL. Perhaps history effects do assert themselves in the concurrent situation in a small proportion of individuals, for as yet undetermined reasons. But the present study indicates that such effects are atypical.

In summary, it has been demonstrated that still another variable may be added to the list of those that affect human FI performance. An alternative schedule of reinforcement concurrently available to the person strongly determines his behavior on FI. Certainly, further research in this area is warranted, since much of human behavior is governed by interval schedules in the context of a larger complex of concurrent contingencies.

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