COMPETITIVE FIXED-INTERVAL PERFORMANCE IN HUMANS

WILLIAM BUSKIST AND DAVID MORGAN

AUBURN UNIVERSITY

Two persons responded in the same session in separate cubicles, but under a single schedule of reinforcement. Each time reinforcement was programmed, only the first response to occur, that is, the response of only one of the subjects, was reinforced. "Competitive" behavior that developed under these conditions was examined in three experiments. In Experiment 1 subjects responded under fixed-interval (FI) 30-s, 60-s, and 90-s schedules of reinforcement. Under the competition condition, relative to baseline conditions, the response rates were higher and the pattern was "break-and-run." In Experiment 2, subjects were exposed first to a conventional FI schedule and then to an FI competition schedule. Next, they were trained to respond under either a differential-reinforcement-of-low-rate (DRL) or fixed-ratio (FR) schedule, and finally, the initial FI competition condition was reinstated. In this second exposure to the FI competition procedure, DRL subjects responded at lower rates than were emitted during the initial exposure to that condition and FR subjects responded at higher rates. For all subjects, however, responding gradually returned to the break-and-run pattern that had occurred during the first FI competition condition. Experiment 3 assessed potential variables contributing to the effects of the competitive FI contingencies during Experiments 1 and 2. Subjects were exposed to FI schedules where (a) probability of reinforcement at completion of each fixed interval was varied, or (b) a limited hold was in effect for reinforcement. Only under the limited hold was responding similar to that observed in previous experiments.

Key words: competition, fixed-interval competition schedule, limited-hold procedure, break-and-run response pattern, lever press, humans

Situations in which the reinforcement of an individual's behavior depends, to some extent, on the behavior of one or more other individuals are characterized as social (Hake & Olvera, 1978; Hake & Vukelich, 1972; see also Parrott, 1983). When the reinforcement of one person's responding depends on the other person's responding *not* being reinforced, the situation may be characterized as "competitive." Such conditions have been referred to by Deutsch (1962) as examples of "contrient interdependence," in which subjects' outcomes are negatively correlated. Under conditions of competition, there are, at any moment, fewer reinforcers programmed than there are persons responding; only the responses that fulfill schedule requirements first are reinforced. If the resulting behavior is that of each individual tending to produce reinforcers at the ex-

pense of the other, the behavior as well as the situation may be regarded as "competitive." Other kinds of social behavior are, for example, "sharing," in which individuals take turns responding after each reinforcement so that reinforcers are distributed fairly evenly (e.g., Hake, Vukelich, & Olvera, 1975) and various forms of cooperation, such as those in which subjects take turns responding, or in which effort is shared, and the responses of one person result in the reinforcer becoming available for the other (e.g., Hake et al., 1975).

Operant research into competitive behavior has been concerned mainly with the question of whether, given the choice, competition or cooperation will be selected, and with the analysis of factors that determine that selection. For example, Lindsley (1966) found that when individuals were given an opportunity to compete for money, they chose instead to take turns so that each person received about the same amount of money across sessions. Competition was produced only when conditions of inequitable reinforcement were set up.

In an experiment by Schmitt (1976), pairs of subjects were given choices between competing and cooperating or responding individ-

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ually without interacting with another person. When the alternatives were competition versus working alone, competition was preferred, regardless of whether subjects could profit by such a choice. When the alternatives were competition and cooperation, competition was chosen only when such a choice proved profitable.

In another series of experiments (Hake, Olvera, & Bell, 1975; Olvera & Hake, 1976), subjects were given choices to cooperate with or to compete against another individual, in gaining access to matching-to-sample problems. Correct responses on the matching-to-sample problem produced points on a counter, which later could be exchanged for money. With increases in the response requirement for access to the problems, subjects switched from competition to cooperation, responding decreased, and reinforcer equity (i.e., correspondence between the number of reinforcers received by subject pairs) increased.

Buskist, Barry, Morgan, and Rossi (1984) found that response rates increase substantially in a competitive situation relative to comparable individual baseline responding. In an ABAB design, college students participating in dyads were first trained on a conventional fixed-interval (FI) schedule whereby responses could produce points on a counter. Next, each dyad received instructions pertaining to competition and was then exposed to a "competitive" FI schedule, which delivered points only to the first pair member to respond after the specified interval had elapsed; the other subject's responding went unreinforced. During sessions on the competitive schedule, all subjects exhibited moderate to large increases in response rate, and their cumulative records showed break-and-run patterns. Upon reexposure to the conventional FI schedule, subjects' responding decreased to low rates with little patterning in the cumulative records. Response rates increased and break-and-run patterns were again evident when the competitive FI schedule was reintroduced.

In the present study, pairs of individuals were exposed to FI 30-s, 60-s, and 90-s schedules in which, at the completion of each interreinforcement interval (IRI), the responses of only one person were reinforced (Experiment 1). Experiment 2 investigated the effect of brief training under one schedule upon competitive responding under a subsequent

schedule. Subjects responded under (a) conventional FI schedules, (b) competitive FI schedules, (c) either differential-reinforcement-of-low-rate (DRL) or fixed-ratio (FR) schedules, and finally (d) competitive FI schedules, in that order. In Experiment 3, the effects upon competitive behavior of different reinforcement probabilities and of the presence or absence of a limited-hold contingency were examined.

EXPERIMENT 1

In ordinary life, the competitive aspects of a situation often arise through available time being fixed while the gains to be made during that time may vary, or through the gain per unit of time being fixed while the time available is dependent on performance. Conventional schedules of reinforcement can be incorporated into the laboratory study of these types of competition: Points or other reinforcers may be delivered after specific temporal or response criteria are met, with the "winner" determined by the relative accumulated reinforcers after a specific length of time has elapsed. The particular reinforcement schedule used would determine the characteristics of effective competitive behavior; for example, FR schedules would favor rapid responding, whereas DRL schedules would favor slow but well timed responding. The FI schedule is well suited to this type of research, for the response and temporal criteria are simple and clearly defined. Subjects' behavior under this type of competitive schedule has been found to be extremely uniform with little of the intersubject variability that characterizes most FI research involving human subjects (Buskist et al., 1984). However, subjects in previous research were exposed to only a single parameter (30 s) of the FI schedule. Accordingly, each subject in the present experiment was initially trained on three different temporal values of a conventional FI schedule. Next, the subjects were exposed to competitive versions of these same schedules, in which the first subject whose responding satisfied the response criteria of the schedule was allocated points on a counter.

METHOD

Subjects

Four Auburn University male undergraduates, ages 18 to 20, served as subjects in an

arrangement whereby class credit was contingent upon regular attendance and participation in the experiment, but not upon any characteristics of performance. Upon questioning prior to the experiment, none of the subjects reported having previously participated in behavioral research.

Apparatus

Subjects were seated individually before either of two identical response consoles that were housed in separate sound-attenuating and darkened cubicles (3 m square and 5 m high). The console measured 55 by 31 by 44 cm and sat on a table that was 70 cm high. The front portion of the console slanted upward at an angle of 45°. A 4-digit LED counter was mounted at a height of 18 cm and was located in the center of the console. Directly above the counter at distances of 4 and 16 cm, respectively, were two lights, an amber "run light" and a green reinforcement-feedback light. A row of three small lights (1.2 cm in diameter) was located in the upper left-hand corner of the console. From left to right the colors of the lights were blue, white, and red. In front of each console was a small wooden box (10 by 10 by 10.5 cm) that contained a standard Gerbrands rat lever.

Housed in a room adjacent to the cubicles was a TRS-80® Model 1 microcomputer that controlled the experimental conditions and collected the data.

Procedure

Prior to the experiment the subjects were randomly paired and each subject remained in the same pair throughout the experiment. Experimental sessions were conducted at the same time daily, each session consisting of three consecutive 9-min blocks. Blocks were separated by short "rest" periods of approximately 2 min each.

At the start of the first block, each pair of subjects was read the following instructions:

By depressing this lever you may earn points on this counter [experimenter depressed the lever three times and pointed to counter]. Every lever press however, may not result in accumulating points on the counter. The amber light is a signal that the experimental session has begun; when it goes off permanently, the session is over. Every time you receive points on the counter, the amber light will go off for a

Table 1

The sequence (left to right) in which schedule values were presented in successive blocks for each subject under each experimental condition.

Subjects	Schedule value	
	Independent	Competitive
AB and CH	60, 30, 90	60, 30, 90
	30, 90, 60	90, 60, 30
	30, 60, 90	60, 90, 30
	60, 90, 30	30, 60, 90
MA and PL	60, 30, 90	30, 60, 90
	30, 90, 60	30, 60, 90
	60, 30, 90	60, 90, 30
	90, 30, 60	90, 30, 60

few seconds and the green light will come on. Each illumination of the green light will indicate that you have earned 25 points. These points will be added to any other points which may have already been tallied on the counter. Responding while the green light is on will not affect your point earnings. The red light may or may not be operative during this experiment. When it is operative, its illumination will indicate that the person in the other booth has been awarded the 25 points and you have not. Thus whenever the other person is accumulating points on his/her counter, the red light will come on in this booth.

In addition, subjects were told, "The lights in the upper left-hand corner of the response console will, in some way, aid you in responding on the lever." Any questions regarding the experimental procedure were answered by re-reading the appropriate section(s) of the instructions. A typed set of instructions remained in each booth throughout the experiment. Each subject was then assigned to a cubicle. Subjects were asked to leave any distractive materials (e.g., watches, writing instruments, books, etc.) outside the experimental cubicle.

Independent blocks. For the first two blocks of the experiment, subjects were exposed to an ascending sequence of values of the FI schedule (i.e., FI 10 or FI 20, one block each, in that order) prior to being exposed to the following regimen: Each light in the upper left-hand corner of the console was correlated with one of three reinforcement schedules (red, FI 30; white, FI 60; and blue, FI 90), one of which was in effect for any given 9-min block. Correlated stimulus lights remained illumi-

Fig. 1. Response rates for each subject during successive 9-min exposures to fixed-interval schedules. Numbers in the upper right corner of each panel indicate the FI schedule values. Subjects' initials are in the upper left corner of the top row of panels. Open circles are from independent FI blocks and filled circles are from FI competition blocks.

nated throughout each session. Both pairs of subjects (AB-CH and MA-PL) experienced four 9-min blocks under each schedule value. Table 1 summarizes the sequence of conditions for each pair of subjects.

The illumination of the amber light initiated each block. Once a given response requirement was met, the amber light was darkened for 2.5 s and the green light was illuminated for 2.5 s while 25 points accumulated by ones on the counter. The counter displayed cumulative points earned during each block to each subject but subjects did not have access to the paired subject's score. During independent blocks, one subject's responses

did not affect the other's opportunity to receive points; that is, consoles in each booth were independently operated and controlled during this part of the experiment.

Competition blocks. Following completion of all independent blocks and immediately prior to the first competitive session, subjects were told, "You will now be competing against one another for the points on the counter" and instructions regarding the operation of the red light were repeated (last two sentences of original instructions). Competitive blocks were the same as independent blocks except that a single FI schedule was now in effect for both subjects. The first subject to complete the requirements of the schedule received 25 points accompanied by the 2.5-s green light, while the other subject received only a 2.5-s illumination of the red light.

All subjects agreed not to discuss this experiment with the other pair member until the termination of the experiment. They were permitted to see and talk to each other before and after, but not during the three daily blocks. During each rest period, one of the experimenters informed subjects of the score on the other's counter. Subjects were informed of the details of the study and questions were answered at the end of the experiment.

RESULTS AND DISCUSSION

Figure 1 shows response rates for subjects under both independent and competitive FI conditions. AB and CH comprised the first competing pair and MA and PL formed the second. AB was the only subject who did not show consistent increases in response rates during competitive sessions relative to independent sessions. However, AB did show increased rates during the first block of competition for the FI 30 and FI 60 schedule, and his performance during the first block of competition on the FI 90 schedule equaled his individual FI 90 schedule rate. For all other subjects, the increased rate of responding under competition relative to independent responding was replicated across all three FI values. MA showed the smallest increase in responding, approximately a doubling in rate, whereas CH and PL's response rates increased approximately three- and fourfold, respectively.

Representative cumulative records of subjects' terminal competitive FI performances are

Fig. 2. Representative cumulative records of FI competition performances. The top row of records is from the FI 30-s competition condition, the middle row is from the FI 60-s competition schedule, and the bottom row is from the FI 90-s condition. Numbers under each record indicate block numbers.

Table 2

Number of reinforcers received by each subject in each competitive condition of Experiment 1.

Schedule	Subjects			
	AB	CH	MA	PL
FI 30	11	5	5	11
	10	6	8	8
	6	10	8	8
	10	5	7	9
FI 60	5	3	5	3
	6	2	3	5
	5	3	6	2
	6	2	4	4
FI 90	4	1	3	2
	5	0	1	4
	3	2	2	3
	3	2	3	2

presented in Figure 2. (All records are from the final block of competition under each schedule. Records for PL are displayed from earlier sessions of competition because of mechanical problems in his cumulative recorder.) Each subject, regardless of his response rate and pattern under independent conditions, responded with a consistent break-and-run pattern on the cumulative record during competition.

Responding under a competitive FI contingency, relative to an independent FI contingency, is marked by increased response rates and break-and-run patterns on the cumulative record. However, increases in response rate may not be necessary to compete successfully, particularly when reinforcement during competition is forthcoming at response rates similar to those emitted under independent conditions. (For example, with the exception of the third FI 30-s block, AB consistently obtained more points than CH during competition without increasing his response rate during competitive blocks.) Likewise, it is apparent from a comparison of subjects' response rates and numbers of reinforcers received that response rate during competition bore little relation to reinforcer frequency. This is clear from the response rates of Subjects MA and PL (Figure 1) and the number of reinforcers each received during the FI 60 and FI 90 conditions. These subjects obtained approximately the same number of reinforcers (Table 2) during these blocks, yet PL's re-

sponse rate during competition was notably higher than MA's during the same period.

In summary, these results indicate that when individuals compete under FI conditions, they respond at relatively higher rates than under conventional FI schedules, and changes from pausing to responding occur in an abrupt, break-and-run fashion. Both of these response characteristics are consistent with previous observations of human performance under competitive FI contingencies (Buskist et al., 1984).

EXPERIMENT 2

Across all schedule parameters of the competition condition in Experiment 1, the response rates of 3 of 4 subjects increased relative to rates emitted under independent conditions. Experiment 2 investigated the robustness of these effects by determining the extent to which competitive FI performance is disrupted by an intervening history of training on alternative schedules of reinforcement.

METHOD

Subjects and Apparatus

Eight Auburn University undergraduates, 4 males and 4 females between the ages of 18 and 22, served as subjects in exchange for credit in an introductory psychology course. None of the subjects reported any previous experience with behavioral research. The apparatus was identical to that in Experiment 1.

Procedure

Subjects were assigned to same-gender pairs and given orientation and instructions identical to those of Experiment 1. Competing pairs are listed in Table 3. In the first nine experimental blocks, subjects responded singly under a conventional FI 30-s schedule. During the next six blocks, subjects performed in pairs under the competitive FI 30-s schedule described in Experiment 1. Next, two subject pairs were exposed to independent fixed-ratio (FR) 50 schedules for nine blocks. The other two subject pairs were exposed to independent differential-reinforcement-of-low-rate (DRL) 10-s schedules for the same number of blocks. Next, each pair of subjects was returned to the competitive FI 30-s schedule for six blocks. The small blue light on the console was lit when either the DRL or FR schedule was in

Table 3

Number of reinforcers received by each subject in each competitive condition of Experiment 2. C1 indicates first competitive series and C2 indicates the second competitive series.

Series	Subjects			
	FI/DRL			
	AF	SS	TD	TK
C1	8	10	18	0
	12	6	16	1
	8	10	13	3
	7	11	10	8
	14	4	9	9
C2	4	14	13	5
	13	2	11	7
	9	8	15	3
	13	5	16	2
	6	12	13	5
	7	11	13	5
	6	12	9	9
	FI/FR			
	KK	CB	BT	FB
C1	6	12	18	0
	6	12	18	0
	10	8	18	0
	7	11	11	7
	13	5	3	15
C2	7	11	8	10
	14	4	12	6
	8	10	11	7
	7	11	10	8
	10	8	7	11
	10	8	10	8
	7	11	9	9

effect and the small red light was on when the competitive FI 30-s schedule was in operation. All experimental blocks were 10 min long, and there were three blocks per session, separated by 2-min rest periods. At the conclusion of the experiment each subject was interviewed and debriefed.

RESULTS

Figure 3 shows response rates for subjects given DRL or FR training between exposures to the competitive FI 30-s schedule. Data are from the last three conventional FI and the last three DRL/FR training blocks. Data for the two competitive FI conditions are presented in their entirety. All subjects given DRL training, except TK, showed increased responding under the first FI competition condition relative to their performance under the

Fig. 3. Response rates during four successive conditions for each subject exposed to DRL (left column) or FR (right column) schedules in the third condition. The four conditions are: FI-R (conventional FI schedule; final three of nine blocks are shown); FI-C (FI competition schedule); DRL/FR (conventional DRL or FR schedule; final three of nine blocks are shown); FI-C (FI competition schedule). Initials in upper left corner of each panel denote subjects.

conventional FI schedule. After DRL training, all subjects but TD responded at a lower rate under the second competition condition relative to the first FI competition condition.

All subjects given FR training showed an

AF

Fig. 4. Representative cumulative records of performance under FI competition following DRL training (Subject AF). Numbers indicate block numbers.

increase in responding during the first FI competition condition relative to the conventional FI schedule condition. However, they emitted their highest response rates under the conventional FR schedule condition. Under the second FI competition condition, all subjects given FR training responded near or above their rates under the first FI competition condition.

Figure 4 presents cumulative records from DRL Subject AF during the second series of six competitive FI blocks. These records are representative of the performance of all DRL subjects except SS. During the first reinstatement of the competitive FI schedule, AF responded at a very low rate with only one or a few responses occurring in each interval, after

a long postreinforcement pause (PRP). By the third block of reexposure, response rate had increased and, in the latter stages of this block, a clear break-and-run pattern emerged on the cumulative record. During the remaining blocks, the pattern was clearly break-and-run, although response rate was lower than rates observed under initial competitive FI blocks.

Figure 5 shows cumulative records from FR Subject BT during the six blocks of reexposure to the competitive FI condition. These records are also representative of the performances of FR subjects KK and CB (not shown) but not FB (also not shown). BT showed a break-and-run pattern under the first competitive FI condition. During the first block of the second series of competitive FI

Fig. 5. Representative cumulative records of performance under FI competition following FR training (Subject BT). Numbers indicate block numbers.

contingencies, this subject's response pattern was similar to that from independent FR sessions, although not as steep. Midway through this block, however, the response pattern changed abruptly to the break-and-run pattern characteristic of the performance during the first series of competitive FI blocks. This pattern continued throughout the remainder of the experiment. KK and CB responded in similar fashion except that the break-and-run pattern emerged earlier in the first block. FB, although exhibiting a break-and-run pattern during the first exposure to the competitive FI

condition, responded at a high, steady rate with little or no PRP during the second series of competitive FI blocks.

The number of reinforcers obtained during competitive blocks in Experiment 2 are presented in Table 3. Comparison of these data with response-rate data from Figure 3 reveals, consistent with similar data from Experiment 1, no systematic relationship between response rate and reinforcement rate under competitive conditions. This finding is similarly demonstrated in Figure 6, which shows the logarithms of the ratios of Subject A's re-

Fig. 6. Logarithm of the ratios of Subject A's response rate to Subject B's response rate as a function of the logarithm of the ratios of reinforcers earned by Subjects A and B in Experiments 1 (upper panel) and 2 (lower panel). Data are from all competitive blocks and initials in upper left corner of each panel indicate subjects.

sponse rate to Subject B's response rate as a function of the logarithm of the ratios of reinforcers earned by Subjects A and B in Experiments 1 (upper panel) and 2 (lower panel). Although there was some tendency for higher rate responders to acquire more competitive reinforcers than their lower rate opponents, several exceptions to this finding make the

contribution of response rate to competitive performance, at least under FI schedules, equivocal. Subject BT, for example, responded at a rate considerably lower than that of his opponent, FB, but nevertheless acquired more reinforcers in four of six sessions of reexposure to FI competition (see C2, Table 3). Similarly, AF acquired more reinforcers than her opponent, SS, during the first three reexposure sessions of FI competition sessions despite the fact that SS's response rate was more than three times that of AF.

DISCUSSION

The findings from the present experiment replicate those from Experiment 1 and indicate consistent, robust effects of the FI competition schedule. Typical competition performance was modified when subjects were trained under different schedules of reinforcement (i.e., prior exposure to other schedules of reinforcement did have some effect upon performance under a different set of conditions). However, between-subject differences observed in Experiment 1 were not likely due to history effects inasmuch as those observed in the present experiment were only temporary, as evidenced by the changes in response rates and patterns after reexposure to the second series of competitive FI contingencies. Weiner (1964) has shown that prior experimental history may have strong effects on human schedule performance, some of which may persist for long periods of time. It is likely that the duration of these effects depends in part on the extent and duration of prior training.

EXPERIMENT 3

Experiments 1 and 2 demonstrated that, when compared to performance under conventional FI conditions, the general effects of exposing subjects to a competitive FI schedule were an increase in response rate and a break-and-run response pattern. These changes in responding might reasonably be attributed to contingencies impinging upon one subject's responding resulting partly from the other subject's behavior. For example, with very few exceptions, subjects in Experiments 1 and 2 experienced a reduction in reinforcement probability during competition relative to independent conditions. There was also reduced availability of reinforcement immediately fol-

lowing termination of the fixed interval; in essence, competition introduced a limited-hold contingency (Ferster & Skinner, 1957). The purpose of Experiment 3 was to evaluate the relative contributions of changes in reinforcement probability and of the limited-hold contingency to performance on the competitive FI schedule.

METHOD

Subjects and Apparatus

Eight Auburn University undergraduates (4 males and 4 females, 18 to 20 years of age) served as subjects. None of the students had participated in previous behavioral research. The apparatus was identical to that in Experiments 1 and 2.

Procedure

Subjects were run in same-gender pairs that were kept constant throughout the experiment. Experimental sessions were conducted at the same time daily, Monday through Friday. Prior to the beginning of the experiment, each subject was read instructions identical to those initially received by subjects in Experiments 1 and 2, except that instructions regarding the function of the red light were omitted. Subjects were told only that "the red light may or may not be operative during this experiment." However, subjects in this experiment did not receive subsequent instructions pertaining to competition, nor were they ever exposed to the competitive FI schedule.

Subjects were notified of each other's point totals at the end of each session in the same manner as in the previous two experiments. Also, as in Experiments 1 and 2, subjects were permitted to see and talk with one another before and after, but not during sessions, and they agreed not to discuss the experiment with one another until it was terminated. Blocks were 10 min long, and there were three blocks per session, separated by 2-min rest periods. Subjects were interviewed and debriefed at the conclusion of the experiment.

Reinforcement probability condition. After nine blocks of training on the regular FI 30-s schedule, 4 subjects (BK, JO, CC, and WM) were exposed to six blocks during which reinforcement probability was varied. Taking CB's performance in Experiment 2 as representative of subjects exposed to competitive FI

contingencies, all subjects were yoked to reinforcement rates that had been obtained by this subject during her six initial blocks of the competitive FI schedule (see Table 3). Hence, subjects in this condition received a maximum of 67% of available reinforcers (12 of 18 possible) during Block 1 and 67%, 45%, 61%, 28%, and 61% of available reinforcers during Blocks 2 through 6, respectively. During these blocks, subjects received points on the counter and illumination of the green light according to the FI 30 schedule only during those inter-reinforcement intervals (IRIs) for which reinforcement was scheduled. The termination of an IRI for which reinforcement was not preprogrammed was followed by illumination of the red light (2.5 s) and no counter incrementation, irrespective of subjects' responses. To accurately simulate competitive FI contingencies, the red light was illuminated independently of the subject's behavior, at the end of the 30-s interval. Reinforcer availability for any subject was not affected by the behavior of the other pair member.

Limited-hold condition. After nine blocks of initial training on the conventional FI 30 schedule, the remaining 4 subjects (JB, DM, BA, and LA) were exposed to six blocks in which a limited hold of 1 s was superimposed on the FI 30 schedule. The green light was lit and subjects received counter points only if a response occurred within the 1-s limited-hold interval. Failure to respond during the limited-hold interval resulted in illumination of the red light and no counter incrementation. Again, reinforcer availability for any subject was not affected by the behavior of the other pair member.

RESULTS AND DISCUSSION

Figure 7 shows response rates for subjects in Experiment 3 during the last three conventional FI blocks and during all subsequent probability or limited-hold blocks. Relative to their regular FI performance, probability Subjects BK, JO, and WM showed a consistent decrease in response rate after the probability of reinforcement was reduced. Response rates, however, did not appear to bear any parametric relationship to reinforcement probability. BK, for example, emitted highest rates during both highest (67%, second) and lowest (28%, fifth) reinforcement probability blocks. CC was the only subject on the re-

Fig. 7. Response rates of subjects for whom reduced probability of reinforcement was superimposed on an FI schedule (left panels) and of subjects for whom a 1-s limited-hold condition was superimposed on the FI schedule (right panels). R is the conventional FI condition, P is the probability condition, and LH is the limited-hold condition.

duced-probability procedure who consistently responded more rapidly during blocks with reduced probability than during previous conventional FI blocks. All subjects exposed to the limited-hold procedure showed increased response rates relative to rates obtained during conventional FI blocks.

Figure 8 shows cumulative records of some subjects from Experiment 3. Records in the left column of this figure are representative of subjects' responding under the conventional FI schedule. Records in the upper right portion of the figure are representative of subjects' responding under the limited-hold condition. (Records from the final block are missing due to mechanical failure.) JB, who showed a large increase in response rate under the limited-hold condition, responded at a high rate, pausing briefly after reinforcer deliveries. DM also evidenced a considerable increase in response rate and her record clearly reveals the emergence of a break-and-run pattern of responding similar to those emitted by subjects actually exposed to competitive contingencies in Experiments 1 and 2. BA developed lower rate break-and-run patterns of responding, as did LA (not shown).

BK's (also representative of CC's responding) and JO's (also representative of WM's responding) cumulative records under reduced-probability conditions are presented in the lower right-hand portion of Figure 8. Generally, the records reveal relatively flat slopes consistent with the decreased response rates of subjects under conditions with reduced probability of reinforcement.

These results suggest that the increased response rates and break-and-run response patterns emitted by subjects under competitive contingencies in Experiments 1 and 2 were likely due to the limited reinforcer availability characterizing subjects' response interaction during the competitive FI contingency. The limited-hold condition in Experiment 3 was sufficient to produce increases in response rates over those that occurred under independent conditions, and, for all subjects, the slight to moderate postreinforcement pauses revealed in the cumulative records. A decrease in reinforcement probability by itself, which usually but not necessarily obtains under competitive conditions (relative to conventional FI conditions), did not prove sufficient to produce either increases in response rate or break-and-run response patterning.

GENERAL DISCUSSION

The results may be summarized as follows: (1) A subject's response rate under conventional FI schedules was lower than that under the same schedule but in competition with another subject; (2) under competition, the pattern of FI performance was break-and-run; (3) these two features of competitive performance occurred regardless of changes in the number of reinforcers delivered; (4) under the competitive FI procedure, performance was only temporarily affected by the history of DRL or FR training; and (5) when the limited-hold condition was introduced, characteristics of individual responding were similar to those observed under competitive FI conditions.

Although in general the effect of the competition contingency was increased response rate, this occurred gradually, across several blocks. AB was the only subject in Experiment 1 whose response rate was at its maximum level in the first block (Figure 1). For the other subjects, highest rates were recorded in 2 to 3 blocks. Similar results were obtained in Experiment 2 for performance under the initial competitive FI schedule (Figure 3). Although rates of responding increased under the competition conditions, the highest rates were not the highest possible for the subjects. As the data from Experiment 2 indicate, under the FR schedules the subjects could respond at even higher rates.

Competitive contingencies exerted strong control over response patterns of subjects in the first two experiments. Eleven of the 12 subjects responded with the break-and-run pattern when competition was in effect and not when responding individually. Under conventional FI contingencies, humans have been reported to respond with a wide variety of patterns. This variety in response patterns is sometimes accounted for by subtle differences in instructions—those provided by the experimenter, those produced by the subject ("self-instructions"), or some combination of the two (e.g., see Lowe, 1979; Weiner, 1983). That is, verbal instructions are believed to interfere with the control that arises, in animal studies, solely from the experimental contingencies. In the present study, however, the break-and-run pattern developed as the predominant pattern regardless of the experimental instructions and also regardless of what kinds of pattern were

Fig. 8. Representative cumulative records of performance under conventional FI contingencies (final block) and subsequent probability and limited-hold conditions. Records in the top panel are from 3 subjects under the limited-hold condition and records in the bottom panel are from 2 subjects under the probability condition. Numbers under each record indicate block numbers.

observed under the independent FI, DRL, or FR conditions. Thus, the addition of the competitive contingency to the conventional FI schedule appears to mitigate the control over behavior exerted by instructions or other "external" variables, and produces response patterns that approach those of nonhuman animals such as rats and pigeons.

In the present study, the proficiency with which subjects fulfilled the schedule requirements was not constrained or limited by experimental controls. One consequence of this was that often one of the subjects received most or all of the reinforcers. Under these circumstances, the behavior of both the "winning" and the "losing" subjects may be affected, not only by the reinforcement actually received, but also by the reinforcement of the other subject's behavior. In other words, the "winner's" behavior may be affected by the nonreinforcement of the "loser's" behavior, and vice versa. These complex relations are entailed in competitive behavior, and for that reason, they should be examined in future research.

REFERENCES

- Buskist, W. F., Barry, A., Morgan, D., & Rossi, M. (1984). Competitive fixed interval performance in humans: Role of "orienting" instructions. *Psychological Record*, *34*, 241-257.
- Deutsch, M. (1962). Cooperation and trust: Some theoretical notes. In M. R. Jones (Ed.), *Nebraska symposium on motivation* (Vol. 10, pp. 275-319). Lincoln: University of Nebraska Press.
- Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement*. New York: Appleton-Century-Crofts.
- Hake, D. F., & Olvera, D. (1978). Cooperation, competition, and related social phenomena. In A. C. Catania & T. A. Brigham (Eds.), *Handbook of applied behavior analysis: Social and institutional processes* (pp. 208-245). New York: Irvington.
- Hake, D. F., Olvera, D., & Bell, J. C. (1975). Switching from competition to sharing or cooperation at large response requirements: Competition requires more responding. *Journal of the Experimental Analysis of Behavior*, *24*, 343-354.
- Hake, D. F., & Vukelich, R. (1972). A classification and review of cooperation procedures. *Journal of the Experimental Analysis of Behavior*, *18*, 333-343.
- Hake, D. F., Vukelich, R., & Olvera, D. (1975). The measurement of sharing and cooperation as equity effects and some relationships between them. *Journal of the Experimental Analysis of Behavior*, *23*, 63-79.
- Lindsley, O. R. (1966). Experimental analysis of cooperation and competition. In T. Verhave (Ed.), *The experimental analysis of behavior: Selected readings* (pp. 470-501). New York: Appleton-Century-Crofts.
- Lowe, C. F. (1979). Determinants of human operant behaviour. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour: Vol. 1. Reinforcement and the organization of behaviour* (pp. 159-192). Chichester, England: Wiley.
- Olvera, D. R., & Hake, D. F. (1976). Producing a change from competition to sharing: Effects of large and adjusting response requirements. *Journal of the Experimental Analysis of Behavior*, *26*, 321-333.
- Parrott, L. J. (1983). Defining social behavior: An exercise in scientific system building. *Psychological Record*, *33*, 533-550.
- Schmitt, D. R. (1976). Some conditions affecting the choice to cooperate or compete. *Journal of the Experimental Analysis of Behavior*, *25*, 165-178.
- Weiner, H. (1964). Conditioning history and human fixed-interval performance. *Journal of the Experimental Analysis of Behavior*, *7*, 383-385.
- Weiner, H. (1983). Some thoughts on discrepant human-animal performances under schedules of reinforcement. *Psychological Record*, *33*, 521-532.

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