SOME EFFECTS OF RESPONSE-CORRELATED INCREASES IN REINFORCER MAGNITUDE ON HUMAN BEHAVIOR

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After training under short or long fixed-interval schedules, humans responded under a modified fixed-interval schedule in which magnitude of reinforcement (X or 2X) was minimally correlated with response frequency. Response frequencies that equaled or exceeded a minimum response criterion were followed by the larger reinforcer at the end of the interval; otherwise, the smaller reinforcer was delivered. The modified schedule alternated with the baseline schedule across conditions. In a control condition, the reinforcer magnitudes produced by control subjects were yoked to those of experimental subjects. Experimental subjects, but not control subjects, showed increased responding. In addition to the baseline and modified fixed-interval schedules used in Experiment 1, subjects in Experiment 2 also responded under a second modified fixed-interval contingency in which increases in reinforcer magnitude were more highly correlated with response frequency. Experimental subjects, but not control subjects, showed increased responding under both procedures. Direct comparison of these two procedures showed that the high-correlation procedure produced greater increases in responding than did the low-correlation procedure.

Key words: adjusting reinforcer magnitude procedure, yoked procedure, reinforcer magnitude, response-reinforcer magnitude correlation, space bar press, humans

Although specific responses and reinforcing stimuli studied have differed, investigations of reinforcer magnitude may be characterized according to the relations between response properties and reinforcer magnitude. Those relations may be conceived as correlations that vary in terms of degree (high or low) and direction (positive or negative) (Gentry & Eskew, 1984; Logan, 1960). A positive correlation between response frequency and reinforcer magnitude may be established by making larger reinforcer magnitudes dependent on either shorter interresponse times (e.g., Hendry, 1962) or a greater number of responses per interval (e.g., Gentry & Eskew, 1984). Compared to control conditions in which reinforcer magnitude is delivered independently of response frequency, the effects of both these procedures have, of course, been found to be similar: Response rates were higher under correlated conditions than under control conditions.

Hendry (1962) and Hendry and Van-Toller

(1964) arranged a negative correlation between response frequency and reinforcer magnitude by making larger reinforcer magnitudes contingent on longer final interresponse times. Response rates under both fixed-interval (FI) schedules (Hendry, 1962) and fixed-ratio (FR) schedules (Hendry & Van-Toller, 1964) were lower for subjects under the negatively correlated condition than for control subjects. In parametric studies in which reinforcer magnitude is manipulated but is not correlated with changes in response frequency, increases in magnitude often decrease responding relative to baseline levels (Harzem, Lowe, & Pridle-Higson, 1978; Staddon, 1970; but cf. Kee-sey & Kling, 1961).

To vary the degree of specified correlation between response frequency and reinforcer magnitude, a fixed or minimum degree of positive correlation, for example, can be specified by making the larger of two magnitude values dependent on response frequencies above a certain criterion and the smaller value dependent on response frequencies below the criterion (Hendry, 1962; Hendry & Van-Toller, 1964). The degree of correlation can be changed by making the criteria more complex. For example, instead of one criterion, two criteria can be used in such a way that reinforcer magnitude is graded according to response fre-

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quency. Thus a very high degree of correlation can be established by increasing the magnitude by a given amount for every specified increase in response frequency (Gentry & Eskew, 1984; Hendry, 1962). These two procedures for arranging the degree of correlation between response frequency and reinforcer magnitude have not yet been compared directly.

Previous research concerning the effects, compared across experimental conditions, of reinforcer magnitude on human behavior has involved only noncorrelated manipulations of reinforcer magnitude; changes in reinforcer magnitude have not been made dependent on changes in response frequency (e.g., McDowell & Wood, 1984; Schmitt, 1974). For this reason, comparisons of the effects of reinforcer magnitude on human responding with those of the nonhuman subjects in the Hendry (1962) and Gentry and Eskew (1984) experiments are not meaningful, and suggest the importance of investigating the effects of response-correlated increases in reinforcer magnitude on human behavior. In the present experiments we investigated the effects of specifying two degrees of positive correlation between response frequency and reinforcer magnitude on human FI performance.

EXPERIMENT 1

METHOD

Subjects

Ten male Auburn University undergraduates, aged 18 to 21, served as subjects in exchange for extra course credit. Extra credit was contingent on attendance at experimental sessions and not on the quality of subjects' performances. None of the subjects reported having previous experience with behavioral research.

Apparatus

A TRS-80 Model 4[®] microcomputer was programmed so that responses on the space bar produced points in two different places on the monitor. Total points accumulated during each session appeared in the upper right corner of the monitor under the words "Total Session Points." The number of points delivered at the end of every interreinforcement interval (hereafter called interval) was tallied in the lower right corner under the words "Points Earned

This Time." The microcomputer sat on a 70-cm high table inside a 3-m square room and was also programmed to present instructional stimuli and to collect response data. During any given interval the words "You May Respond" appeared on the center of the monitor. During point delivery this message was altered to read "Do Not Respond."

Procedure

Subjects were seated before the microcomputer in the cubicle and the following instructions were displayed on the monitor:

Thank you for your willingness to participate in this experiment. This project is concerned with human problem solving. Your task is simply to earn as many points as possible in each session. Points may be earned by depressing the space bar. In between sessions, there will be a few minutes for rest. Three or four sessions will be conducted daily. Once you have read and understood these instructions, please hit the space bar and prepare to begin the experiment. If you have any questions regarding the experiment, please ask one of the experimenters before hitting the space bar.

For the first several sessions of the experiment, 3 subjects responded under an FI 30-s schedule of reinforcement, and 2 subjects responded under an FI 90-s schedule. Each response that satisfied the FI contingency produced 20 points on the monitor that were tallied, by ones, under the "Points Earned This Time" message. Points also were summed concurrently under the cumulative message ("Total Session Points Earned").

Once responding stabilized (no more than 10% variability in mean response rate, plus or minus, over four consecutive sessions) subjects were exposed to the following adjusting procedure for increasing reinforcer magnitude: If the number of responses during any one interval was less than a prespecified percentage increase in that subject's average number of interval responses in the preceding four baseline sessions, that interval ended with 20 points being tallied under the "Points Earned This Time" message. However, if the number of responses emitted by a subject equaled or exceeded the prespecified criterion, that interval ended with 40 points being tallied under the same message. For example, during Condition 2 subject MO (see Table 1) received 40 points only if he had emitted five or more responses;

at the end of intervals in which four or fewer responses occurred only 20 points were delivered. The criterion was determined by calculating each subject's average number of interval responses during the last four sessions in the immediately preceding condition and then multiplying it by an arbitrary percentage value that was chosen after examination of the range of the number of responses per interval in that condition. For example, a subject may have averaged eight responses per interval with a range of 2 to 14 responses. An increase of 50% [$8 + (8 \times 0.5)$] would therefore result in a new criterion of 12 responses. A subject with the same average number of responses per interval but with a smaller range (e.g., 4 to 10 responses) would be given a lower criterion [$8 + (8 \times 0.25) = 10$]. Thus the criterion always fell within the range of responding observed for any particular subject during the last four sessions in the immediately preceding condition. Each subject was exposed to several different conditions involving various response criteria for adjustment of reinforcer magnitude. The specific response criteria for each subject are given in the third column of Table 1. Regardless of changes in response criteria, subjects responded under the FI schedule on which they were originally trained.

Each of the remaining 5 subjects was yoked to an experimental subject such that each earned the same number of points per interval as his respective experimental counterpart. Each yoked subject was exposed to the same sequence of experimental events, including instructions, as experimental subjects except for the adjusting reinforcer magnitude contingency. Thus yoked subjects received response-independent changes (increases or decreases) in reinforcer magnitude. Experimental and yoked subjects were not studied simultaneously.

Subjects participated in three or four 10-min sessions daily. Each session was separated by a 3-min rest period. Subjects, schedules, condition sequences, number of sessions per condition, and minimum number of responses required to increase reinforcer magnitude per condition are given in Table 1. Subjects were interviewed at the end of the experiment.

RESULTS

Response rates (responses per minute) for each subject are shown in Figures 1 (FI 30 s)

and 2 (FI 90 s). Closed circles represent response rates (responses per minute) of experimental subjects, and open circles represent response rates of yoked subjects. All experimental subjects responded at low rates during baseline sessions. During each response-correlated reinforcer magnitude condition, each of these subjects showed increased responding. The value of the FI schedule did not differentially affect the subjects' sensitivity to adjustments in reinforcer magnitude. The size of the increase in responding varied among subjects from a doubling in rate (MO), to a five-fold increase (KW), to an 18-fold increase (JJ). In comparison, each yoked subject responded at a stable, low rate throughout all phases of the experiment.

For each subject, the mean number of responses emitted per interval and the percentage of intervals ending with the larger magnitude are given in the last two columns of Table 1. Reinforcer magnitude increased close to or above 90% of the intervals during the adjusting reinforcer magnitude conditions for all experimental subjects except MO. Comparison of Columns 4 and 6 shows that during each correlated condition, the average number of responses per interval emitted by each experimental subject exceeded the minimal response requirements for obtaining the larger magnitude of reinforcement.

Comparison of the performances of experimental and yoked subjects indicates that increasing reinforcer magnitude independently of responding is not sufficient to increase responding. The correlation between responding and reinforcer magnitude thus was critical in controlling subjects' behavior when reinforcer magnitude was manipulated.

EXPERIMENT 2

In Experiment 1, any increase in responding equal to or exceeding criterion levels produced a fixed, two-fold increase in reinforcer magnitude. The correlational contingency between increases in reinforcer magnitude and increases in responding constituted only a minimum response requirement: If response frequency was above the criterion, the magnitude was large; if response frequency was below the criterion, magnitude was small. Gentry and Eskew's (1984) research suggests a correlational procedure involving more but smaller gradations: More responding produces pro-

Table 1

Subjects, schedules, conditions, sessions per condition and response information from Experiment 1. Data in the last columns were obtained by averaging over the last four sessions of each specific condition. Information in parentheses denotes data from yoked subjects.

Subject	Schedule	Condition	Minimum required responses	Sessions	Mean no. responses per interval	Percentage of intervals ending with the larger magnitude
MO(VI)	FI30	Baseline	—	8	3.2 (3.1)	—
		3 × 67%	5	7	6.4 (2.5)	83
		6 × 34%	8	5	8.2 (2.0)	82
		8 × 50%	12	6	12.4 (3.7)	93
		Baseline	—	8	7.7 (2.1)	—
		7 × 50%	11	6	11.5 (3.8)	95
KW(SM)	FI30	Baseline	—	11	2.2 (5.5)	—
		2 × 50%	3	6	24.6 (8.1)	99
		Baseline	—	5	4.3 (6.2)	—
		4 × 100%	8	6	24.3 (4.4)	99
		Baseline	—	10	4.4 (3.1)	—
		4 × 100%	8	6	24.5 (3.3)	99
JJ(MW)	FI30	Baseline	—	11	4.1 (3.9)	—
		4 × 50%	6	6	22.3 (7.0)	96
		22 × 25%	28	6	42.7 (4.3)	90
		42 × 75%	74	6	83.5 (2.1)	89
		Baseline	—	9	1.8 (2.1)	—
		26 × 25%	33	7	38.6 (1.8)	94
DD(GH)	FI90	Baseline	—	8	2.0 (3.3)	—
		2 × 50%	3	8	19.8 (1.3)	100
		18 × 34%	24	12	180.0 (1.4)	100
		Baseline	—	8	3.8 (1.4)	—
		2 × 100%	4	8	180.5 (1.2)	100
FT(SB)	FI90	Baseline	—	8	1.4 (3.9)	—
		1 × 100%	2	8	4.4 (1.7)	100
		4 × 75%	7	8	52.9 (1.5)	96
		Baseline	—	8	10.3 (1.2)	—
		10 × 20%	12	8	37.1 (1.5)	96

portionally more reinforcement. A direct comparison of these two correlational procedures would identify the effects of increasing the degree of correlation between response frequency and reinforcer magnitude. In Experiment 2 we investigated the effects of increasing reinforcer magnitude proportional to the size of the increase in the subject's responding: The more responses emitted by a subject during any interval, the greater the number of points that appeared on the monitor at the end of that interval.

METHOD

Subjects and Apparatus

Four Auburn University undergraduates, 2 males and 2 females between the ages of 18 and 21, served as subjects in exchange for extra

course credit. As in the first experiment, extra credit was dependent on attendance at daily sessions and not on performance. None of the subjects reported previous experience with behavioral research. The same apparatus was used as in Experiment 1.

Procedure

Orientation and instructions given to subjects in Experiment 2 were identical to those used in Experiment 1. Subjects first were exposed to an FI 60-s schedule of reinforcement (baseline), and then to an adjusting contingency similar to those used in Experiment 1. During the third and fifth conditions of the experiment the adjusting contingency was altered so that instead of receiving 40 points when meeting or exceeding the response cri-

terion, each subject received three additional points over and above the usual 20 points (baseline level of reinforcement) dependent on each 5% increase in the number of responses emitted per interval. Thus, the number of points each subject could earn per interval was, in principle, unlimited. For example, if a subject averaged 10 responses per interval during baseline conditions and emitted 24 responses during a particular interval of the unlimited magnitude condition (UNL), 170 points were delivered at the end of that interval. Interspersed between the third and fifth condition was a second baseline (regular FI 60 s) condition. The remaining 2 subjects were each yoked to an experimental subject in the manner described in Experiment 1.

Subjects, conditions, the number of sessions per condition, and the minimum number of responses required to increase reinforcer magnitude are given in Table 2. Subjects were interviewed at the end of the experiment.

RESULTS

Response rates (responses per minute) are presented in Figure 3. Closed circles represent the response rates of experimental subjects WD and JB, and open circles represent the response rates of yoked subjects MJ and JN. The numbers preceding "UNL" in the legend represent the number of responses used to calculate the adjusting contingency.

WD and JB showed modest increases in response rate during Condition 2. Both subjects showed dramatic and sustained increases in responding during the two conditions in which increases in reinforcer magnitude were proportional to the size of the increase in their responding (Conditions 3 and 5). The mean number of responses per interval during the final four sessions of Conditions 3 and 5 were similar for both WD (465.5 and 459.2) and JB (356.7 and 350.0) (see Table 2). In contrast, both yoked subjects emitted stable, low response rates throughout all conditions of the experiment, regardless of the magnitude of programmed reinforcement (see Figure 3 and Table 2). The percentage of intervals ending with an increase in reinforcer magnitude and the mean number of points delivered per interval are given in the last three columns of Table 2. During each session involving the adjusting contingency (Conditions 2, 3, and 5)

Fig. 1. Response rates (responses per minute) for subjects who responded under the FI 30-s schedule of reinforcement. Closed circles represent data from subjects exposed to a contingent reinforcer magnitude procedure and open circles represent data from yoked subjects. "Base" represents baseline conditions, and other designations represent the experimental conditions in terms of the specific criteria for establishing the minimum number of required responses.

both WD and JB earned the maximum number of increases in reinforcer magnitude.

DISCUSSION

The results from Experiments 1 and 2 show that positively correlated changes in reinforcer magnitude increase human subjects' responding under FI schedules relative to their baseline levels of responding and relative to yoked control subjects' responding, and that such increases are larger under the graded, unlimited

Fig. 2. Response rates (responses per minute) for subjects who responded under the FI 90-s schedule of reinforcement. See Figure 1 for further explanation.

magnitude condition (high correlation) than under the fixed magnitude condition (low correlation). These results extend to human behavior some of the findings of Hendry (1962) and Gentry and Eskew (1984), who used animals as subjects. The findings are similar with respect to the observed increases in response rates

during positively correlated conditions when compared to the response rates of control subjects. Increases in responding, relative to baseline levels of responding, were not reported by Hendry (1962) and were not observed for all subjects in Gentry and Eskew's (1984) experiment. Gentry and Eskew used an auto-maintenance procedure that produced a vari-

Table 2

Subjects, schedule, conditions, number of sessions per condition, mean number of responses, percentage of intervals ending with an increase in reinforcer magnitude, and mean number of points received per interval for the last four sessions of each condition. Information in parentheses represents data from yoked subjects.

Subject	Schedule	Condition	Sessions	Mean no. responses per interval	Percentage of intervals ending with the larger magnitude	Mean number points per interval
WD(MJ)	FI60	Baseline	7	4.15 (13.9)	—	20
		5 × 60%	8	15.3 (3.3)	100	40
		15 UNL	12	465.5 (1.5)	100	1,804
		Baseline	7	7.4 (1.7)	—	20
		6 UNL	8	459.2 (2.0)	100	4,578
JB(JN)	FI60	Baseline	9	2.9 (3.8)	—	40
		7 UNL	10	356.7 (2.6)	100	3,008
		Baseline	6	4.0 (2.7)	—	20
		4 UNL	8	350.0 (1.5)	100	5,156

able delay between the last response and delivery of the reinforcer at the end of each interval. Unlike that procedure, the FI schedule used here arranged immediate reinforcement. This procedural difference might account for the increase in responding for all subjects in the present experiments.

It is important to note that the notion of "correlation," as used in the present context, does not necessarily favor any one level of explanation because its usage is descriptive. The question of molar versus molecular levels of explanation, for example, was not addressed in the present investigation, for correlation can be specified at different levels, depending on the response properties in question. To illustrate this point, consider the two "correlational" procedures described in the literature. Hendry (1962) and Hendry and Van-Toller (1964) programmed different consequences for different values of the final interresponse times (thus affecting mean interresponse time). Gentry and Eskew (1984) and the present study made increases in reinforcer magnitude dependent on the number of responses emitted in a given interval. The results of these studies are, as one might expect, similar because mean interresponse time is the reciprocal of response rate. Thus an experiment that directly compares a procedure based on correlations between reinforcer magnitude and interresponse times (relatively molecular correlation) with a procedure based on correlations between reinforcer magnitude and response rate (relatively molar correlation) would likely yield results similar to the present study.

Although the present experiments indicate that response-dependent increases in reinforcer magnitude result in higher response rates, it should not be expected that response-independent increases in reinforcer magnitude across experimental conditions would not, in every case, affect responding. This point is supported by studies involving animal subjects in which reinforcer magnitude is manipulated independently of any particular response property (e.g., Harzem et al., 1978; Staddon, 1970). In such cases, response rates often are an inverse function of reinforcer magnitude. Harzem and Harzem (1981) suggested that such results are due to increases in postreinforcement pause duration. According to this account, one would predict that the response rates of yoked subjects in the present experi-

Fig. 3. Response rates (responses per minute) for WD and MJ (top panel) and JB and JN (bottom panel). "UNL" denotes the unlimited magnitude condition. All other designations are the same as in Figures 1 and 2.

ments would be higher during baseline than during control conditions. As can be seen in Figures 1 through 3, however, responding did not differ systematically under the two conditions. This raises some important questions about subject and procedural differences when making human-nonhuman animal comparisons. Subjects' language capacities, responses, reinforcers, apparatus, and deprivation regimens are only a few of the differences between the present work and that reviewed by Harzem and Harzem (1981). Interestingly, these same procedural differences also exist between the present work and that of Hendry (1962) and Gentry and Eskew (1984), suggesting that other variables are involved, and inviting direct, within-subject comparisons of the effects of response-correlated (high, low, and zero) increases in reinforcer magnitude in human subjects.

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