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COLLEGE STUDENTS' RESPONDING TO AND RATING OF CONTINGENCY RELATIONS: THE ROLE OF TEMPORAL CONTIGUITY

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Two experiments investigated the role of temporal contiguity in college students' responding to and rating of contingency relations during operant conditioning. Schedules were devised that determined *when* but not *whether* appetitive or aversive events would occur. Subjects' reports concerning the schedules were obtained by means of a 200-point rating scale, anchored by the phrases "prevents the light from occurring" (−100) and "causes the light to occur" (+100). When tapping a telegraph key advanced the time of point gain, responding was maintained or increased and subjects gave positive ratings. When tapping a telegraph key advanced the time of point loss, subjects also gave positive ratings, but responding now decreased. When key tapping delayed the time of point gain, responding decreased and subjects gave negative ratings. When key tapping delayed the time of point loss, subjects also gave negative ratings, but responding now increased. These findings implicate response-outcome contiguity as an important contributor to causal perception and to reinforcement and punishment effects. Other accounts—such as those stressing the local probabilistic relation between response and outcome or the molar correlation between response rate and outcome rate—were seen to be less preferred interpretations of these and other results.

Key words: contingency relations, response-outcome contiguity, causal perception, ratings of contingency, delay of outcome, college students, telegraph-key tap

Schedules of reinforcement determine how reinforcers are related to prior responses. If responses and reinforcers occur independently of one another, no relationship or contingency is said to exist between the two classes of events. If, however, the temporal distribution of responses determines the temporal distribution of reinforcers, one speaks of a contingent relation existing between responses and reinforcers (Schoenfeld & Farmer, 1970). It is clear that such contingencies have profound effects upon operant behavior (Ferster & Skinner, 1957; Zeiler, 1977). What is less clear is just what feature(s) of reinforcement contingencies is (are) responsible for producing such behavioral effects.

Consider a variable-ratio schedule requiring an average of two responses (VR 2). This schedule imposes a response-reinforcer contingency because the temporal distribution of responses determines the temporal distribution of reinforcers. In the absence of responding, reinforcers are never delivered; reinforcers are delivered immediately after a random half of the responses. But can we be more precise about why the VR 2 schedule controls operant behavior so effectively?

One answer to this question asserts that, at the molar level, increases in the rate of operant responding bring about increases in the rate of reinforcement (Baum, 1973). If more frequent reinforcement is preferable to less frequent reinforcement, then continued exposure to the VR 2 schedule should promote an increase in the rate of operant responding.

A second answer is more molecularly focused and involves the role of response-reinforcer contiguity (Skinner, 1948; Thorndike, 1911). Specifically, operant responses may be strengthened because they immediately precede reinforcers. And even though not every operant response on the VR 2 schedule is immediately followed by a reinforcer, the delays between unreinforced operant responses and later reinforcers should be no longer than the delays between other classes of unreinforced behavior and subsequent reinforcers. On balance, the obtained delays of reinforcement should be shorter after operant responses than after any other class of behavior; the prefer-

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ential performance of operant behavior is thus explicable in terms of temporal contiguity.

A third answer entails the local conditional or probabilistic relationship holding between the occurrence/nonoccurrence of operant responding (R) and the presentation/nonpresentation of a reinforcer (S^*) within relatively small periods of time (Seligman, Maier, & Solomon, 1971). When $p(S^*/R) - p(S^*/\text{no R})$ is greater than zero, the conditional relation between R and S^* is positive and excitatory conditioning should result; when the conditional probability difference is less than zero, the relation between R and S^* is negative and inhibitory conditioning should result; and when the difference is zero, no relation exists between R and S^* and responding should be neither strengthened nor weakened. The VR 2 schedule can then be seen to support high rates of operant responding because intervals of time involving operant responses entail a higher likelihood of reinforcer delivery than those that do not.

From this discussion, it is clear that all three analyses—molar correlation, temporal contiguity, and local probabilistic relation—can account for the effectiveness of the VR schedule. What is needed are new reinforcement schedules that are capable of distinguishing the involvement of each factor in the control of operant behavior.

One recent candidate is the probabilistic reinforcement schedule devised by Hammond (1980; see also Tomie & Loukas, 1983). This schedule determines whether or not to deliver a reinforcer every *t* s, depending upon the occurrence/nonoccurrence of at least one operant response in the last *t* s. With $p(S^*/R)$ each 1 s held constant at .12, the rate of rats' lever pressing maintained by the delivery of water reinforcers fell as $p(S^*/\text{no R})$ was raised from .00 to .08 to .12. This result is to be expected on the basis of accounts of operant behavior that stress the local conditional relationship between responses and reinforcers, since the probability difference scores $[p(S^*/R) - p(S^*/\text{no R})]$ of the above three schedules decrease from .12 to .04 to .00. This result is also to be expected on the basis of the notion of molar correlation, since increases in the rate of operant responding bring about progressively smaller increases in the rate of reinforcement as $p(S^*/\text{no R})$ is raised; of course, when $p(S^*/R) = p(S^*/\text{no R})$, that is, the case of noncontingent reinforcement, changes in the rate of responding have no effect upon the rate of reinforcement. However, considering the role of response-reinforcer contiguity, it is difficult to see why presenting reinforcers in the absence of operant responding should decrease the rate of operant responding, since there is no change in $p(S^*/R)$ and presumably no increase in the delay of reinforcement following operant responses. Thus, it has been argued (e.g., Bloomfield, 1972) that probabilistic reinforcement schedules like Hammond's (1980) reduce or eliminate the involvement of temporal contiguity in schedule performance.

The case against contiguity is further strengthened by the recent finding that college students' telegraph-key tapping maintained by points or money reinforcement is also strongly controlled by probabilistic reinforcement schedules (Chatlosh, Neunaber, & Wasserman, 1985). Also, in that situation, students' ratings of the prevailing response-reinforcer contingencies were very close approximations to the actual local probabilistic relations, whether positive, negative, or zero (see also Wasserman, Chatlosh, & Neunaber, 1983).

Unlike probabilistic schedules, which determine *whether* to deliver reinforcers at specific points in time, other newly devised schedules determine *when* to deliver reinforcers. By design, these schedules can guarantee that changes in the rate of operant responding will not entail any corresponding changes in the rate of reinforcement, thereby eliminating the involvement of molar response-reinforcer correlation in schedule performance. Furthermore, depending upon the time interval used for calculation, these schedules may also question the behavioral relevance of the local conditional relationship between response and reinforcer (e.g., Hammond & Paynter, 1983).

Hineline (1970, 1977) was the first to examine the effects on operant behavior of schedules in which responses could affect *when* but not *whether* an environmental event would occur. He reported that rats' lever pressing was acquired and maintained under procedures that merely delayed inevitable shock presentation (see also Lewis, Gardner, & Hutton, 1976). In addition, Hineline (1977) reported that when lever pressing was established by shock delay, responding was maintained even when lever pressing *increased* the number of shocks received (see also Gardner & Lewis, 1976). Thus, shock delay may reinforce operant behavior to such a degree that it overshadows a positive correlation between response rate and shock rate and a positive probabilistic relation between operant responding and shock delivery.

Work with appetitive reinforcers yields results analogous to those obtained with aversive stimuli. Thomas (1981, 1983) found that rats' lever pressing was acquired and maintained under a procedure that merely advanced inevitable food presentation. Furthermore, he found similar results even when lever pressing *decreased* the number of food presentations (see also Vaughan & Miller, 1984). Again, temporal contiguity overshadowed molar correlation and local conditional relationship in the control of operant behavior.

The present study further investigated the role of temporal contiguity in subjects' responding to and rating of the contingency relations arranged by several schedules of reinforcement. Although interest in causal perception does not preclude the use of animal subjects (e.g., Killeen, 1978, 1981), we undertook the present work partly as an extension of our prior studies on the verbal behavior of college students (Chatlosh et al., 1985; Wasserman et al., 1983). Also, we hoped to assess the species generality of research into the advance and delay of reinforcement, which until now has involved only rats as subjects.

The specific schedules that we used were inspired by those devised by Hineline (1970) and Thomas (1981; see also DeLong & Grisham, 1980). These schedules permitted subjects to advance or to delay appetitive or aversive events, without also affecting (a) the probability of the events occurring within a brief time interval or (b) the correlation between response rate and reinforcement rate over more extended periods of time.

In our study, both appetitive (point gain) and aversive (point loss) outcomes could be advanced and delayed by the subjects' tapping a telegraph key. We compared subjects' operant responding under these schedules with responding under noncontingent schedules to see whether outcome advance and delay reinforced or punished key tapping. After subjects were exposed to each schedule, we asked them to report, by means of a numerical rating scale, the degree to which responding caused or prevented the gain or the loss of points. These ratings were later correlated with subjects' key tapping to evaluate the relation, if any, between how subjects described the prevailing schedules and their operant responding under those schedules.

EXPERIMENT 1

Thomas (1981) conducted two experiments concerned with the effects of contiguous appetitive events on rats' lever pressing. In the first experiment, one food delivery was scheduled every 20 s. Food came at the end of a 20-s interval if no lever presses were emitted; the first lever press in a 20-s interval immediately delivered the food. Lever pressing thus advanced the time of food delivery and made food delivery contiguous with lever pressing; but, evaluated over each 20-s interval, there was no conditional relation between lever pressing and food presentation (food was given once every 20 s, whether the rat pressed or not), and changes in the rate of lever pressing were uncorrelated with the rate of food delivery (each 1-hr session involved 180 feedings, regardless of the rat's rate of responding). All 6 rats' lever pressing increased from near 0 responses per min in the first session to between 22 and 36 responses per min by the 30th session.

In Thomas's second experiment, the rate-enhancing effect of response-reinforcer contiguity was pitted against the possibly rate-suppressing effect of a negative response-reinforcer relation. The schedule was similar to that in the first experiment: Food delivery came at the end of a 20-s interval if no lever presses occurred, and food immediately followed the first lever press in a 20-s interval. However, a response in one 20-s interval could cancel food delivery in the next 20-s interval. Thus, there was a negative correlation between response rate and reinforcement rate; as response rate rose, the obtained rate of reinforcement could fall from 3 per min to 1.5 per min. (Because responding in one interval could delete reinforcement in the next, thereby rendering responding in that next interval ineffective, it is not possible to compute a priori probabilities for this schedule on an interval-by-interval basis.) This negative correlation notwithstanding, the lever pressing of all 6 rats increased from 0 responses per min in the first session to between 6 and 32 responses per min by the 30th session.

Is response-reinforcer contiguity similarly powerful in the control of human behavior? To ascertain, we adapted the procedures of Thomas (1981) for use with college students. In our contiguity (C) schedule, each brief flash of a light signaled the gain of one point. Light delivery occurred every t s without a telegraph-key tap. The first tap in a t-s interval immediately presented the point light. We also sought to pit contiguity against a negative response-reinforcer relation. Thus, under our C− schedule, a response in interval n immediately presented the point light in that interval, but canceled point-light presentation in interval $n + 1$. By monitoring key tapping over the span of 60 t-s intervals, we could see whether our college students' operant responding was strongly controlled by schedules C and C−. By examining postschedule ratings along a 200-point scale, we could also see whether subjects were more likely to report that telegraph-key responding caused the light to occur (+100 on the rating scale) or prevented the light from occurring (−100 on the rating scale) under the two schedules.

Although our main interest was in the effects of contiguity-promoting schedules, we thought it important to include a noncontingent schedule as a baseline against which to assess the effects of response-reinforcer contiguity. Thomas (1981) had not included this control for accidental conjunctions of response and reinforcer. In our I schedule, therefore, the point light was presented every t s, independently of the subject's key tapping. We expected much less operant responding under this schedule than under the C and C− schedules. We also expected subjects to report that responses had no effect on the occurrence of the point light (0 on the rating scale; see Chatlosh et al., 1985; Wasserman et al., 1983).

In any experiment with human adults, the instructions they are given can be of great importance to the obtained results. We certainly did not want subjects to respond at high initial rates on the telegraph key because we wished to see response acquisition if at all possible. Therefore, in an attempt to lower subjects' responsivity, we told them that points could be earned either by tapping or by not tapping the key. In addition, we included in the procedures for each individual subject two schedules designed to decrease telegraph-key responding. In the response-contingent omission (O) schedule, the first tap in a t-s interval omitted presentation of the point light in that interval. In the O− schedule, we included the further negative feature that point-light presentation could be canceled on interval $n + 1$, if the subject tapped the key in interval n. We expected these schedules of reinforcement omission to support even less operant behavior than the I schedule. We also expected subjects to report that on these schedules key tapping prevented the occurrence of the point light (see Chatlosh et al., 1985; Wasserman et al., 1983).

Finally, we reasoned that the longer the sampling interval, t, the greater the extent to which responding could affect the time of reinforcement. Thus, for different groups of subjects, we set t to 3, 6, or 9 s to assess whether these different intervals supported different levels of operant responding or different ratings of the five schedules.

METHOD

Subjects

The subjects were 24 male and 24 female college students, who served in the experiment as one option for fulfilling a course requirement. Subjects were randomly assigned to the 3-, 6-, or 9-s sampling interval conditions, with the restriction that each group contain an equal number of males and females ($n = 8$).

Apparatus

Two stimulus-response panels were used, each located in a separate experimental room. Each panel consisted of a black plywood base (22.8 cm by 18.8 cm) on which a telegraph key was mounted, and a black Masonite upright (27.4 cm by 18.8 cm) attached to the rear edge of the base. Mounted on the upright were red, white, and green jewel fixtures, which could be illuminated from behind by small bulbs. Only the red and white lights were used in this experiment; the green light was included in the procedures of Experiment 2. Mounted on the back of the upright was a relay. Each telegraph-key tap produced a sharp "click" from the relay. A DEC PDP® 8/L minicomputer equipped with a relay interface and the SKED® software system (Snapper, Stephens, & Lee, 1974) was housed in a separate room. The computer system controlled stimulus presentations and recorded subjects' responses.

Procedure

Upon entering the laboratory, subjects were seated at a desk in an experimental room and were read the following instructions by a research assistant:

> In this experiment, you can earn points by getting the white light to come on. Every time the white light comes on, you will earn one point. Tapping the telegraph key or not tapping it may lead to more points being earned.
>
> At any time you may choose to tap the key or not tap it. You may tap the key as many times as you like, or you may refrain from tapping it for as long as you like. However, because of the nature of the task, it is to your advantage to tap the key some of the time and not tap it some of the time. In order to know how to make the light come on as many times as possible, you must know what happens when you tap the key and when you don't tap it. In addition, because your task is to turn on the white light as many times as possible by either tapping or not tapping the key, please do not hold the key down at any time during the experiment.
>
> I would like you to try five different problems, each of which will be a few minutes long. In each case, you can earn points by getting the white light to come on. Because the problems differ from one another, you may earn more points on some problems than on others.
>
> Each of the five problems will begin when the red light comes on and end when it goes off. After each problem, choose the number between −100 and +100 on the rating scale that best characterizes the degree to which your tapping of the telegraph key affected the occurrence of the white light, from "prevents the light from occurring" to "causes the light to occur." Then, write that number in the space provided on the sheet for each problem. In addition, because the problems differ from one another, it is important that you not let your judgment on any given problem affect your judgment on any of the other problems.
>
> The problems will be separated by a minute or so to allow you time to make your ratings. I will return when the problems are over.

Each schedule was signaled by illumination of the red light. Each duration of exposure to a given schedule, designated a problem, comprised 60 unsignaled t-s intervals. Each illumination of the white light lasted 0.10 s.

In the contiguity (C) schedule, the white light occurred every t s without a response; the first response in a t-s interval immediately presented the white light that otherwise would have occurred at the end of the interval. Any additional responses in an interval had no effect on the light. In the C− schedule, the white light occurred at the end of each t-s interval without a response. The first response in interval n immediately produced the light, canceled the light delivery that would otherwise have occurred at the end of interval n, and also canceled the light presentation that would have occurred at the end of interval $n + 1$. Further responses during interval n had no effect on the light, nor did responses during interval $n + 1$, if at least one response had been made in interval n. In the response-independent (I) schedule, the white light occurred at the end of each t-s interval, whether or not a response occurred. In the omission (O) schedule, the light occurred at the end of each t-s interval without a response, but the first response in an interval canceled the light delivery that would have occurred in the absence of responding. Further responses in an interval had no effect on the light. Finally, in the O− schedule, the first response in a t-s interval not only canceled the light delivery that would have occurred at the end of interval n without a response, but also canceled the light delivery that would have occurred at the end of interval $n + 1$. As in the C− schedule, further responses during interval n had no effect on the light, nor did responses during interval $n + 1$, if at least one response had been made in interval n. Depending upon the experimental group, t was set to 3, 6, or 9 s.

The five schedules were presented in a quasi-random manner, such that each problem appeared in each ordinal position with equal frequency for each experimental group (Table 1). After every problem, subjects rated the relationship between key tapping and white-light delivery on a bipolar scale, which ranged from −100 ("responding prevents the light from occurring") to 0 ("responding has no effect on the light") to +100 ("responding causes the light to occur"). The problems were separated by intervals of about 1 min to allow subjects ample time to make their ratings. Responding was scored in terms of the number of intervals out of six in which the subject made at least one key tap. This quotient defined the probability of a recorded response and was collected over 10 successive blocks. (Analysis of subjects' response rates yielded virtually identical results. Because response probability more directly reflects subjects' ac-

Table 1

Order of administration of each of the schedules of Experiment 1 for subjects numbered 1 through 8.

	Schedule				
Subject	C	C−	I	O	O−
1	5	3	2	4	1
2	2	1	4	3	5
3	4	2	5	1	3
4	3	4	1	5	2
5	1	5	3	2	4
6	5	3	2	4	1
7	2	1	4	3	5
8	4	2	5	1	3

tual contact with the schedules, it was chosen for presentation purposes.) After the five schedules were presented, the subjects were carefully debriefed and allowed to leave.

Results and Discussion

Telegraph-Key Responding

Figure 1 shows the mean probability of key tapping under each of the five schedules in successive, six-cycle blocks of training. In the first training block, all five schedules supported highly similar response probabilities, ranging from .64 to .69. However, as training progressed, responding was differently maintained by the five schedules. Responding stayed high under Schedule C, declined slightly under Schedule C−, and dropped dramatically under Schedules I, O, and O−. In the final block, Schedules C, C−, I, O, and O− supported mean probabilities of responding equal to .67, .51, .19, .07, and .13, respectively.

Analyses of variance disclosed that the main effects of blocks of training, $F(9, 405) = 62.16$, $p < .001$, and schedules, $F(4, 180) = 43.36$, $p < .001$, were reliable, as was the blocks by schedules interaction, $F(36, 1{,}620) = 6.96$, $p < .001$. The main effect of sampling interval (3, 6, or 9 s) was not statistically significant, nor did this factor enter into any reliable interactions. Therefore, Figure 1 does not separately portray responding for the three different sampling interval groups.

Because the five schedules maintained different overall probabilities of responding, additional tests were conducted to clarify the nature of the differences. Schedules C and C− together supported reliably more responding than did Schedule I, $F(1, 180) = 20.15$, $p < .001$. Schedule C supported reliably more responding than did Schedule C−, $F(1, 180) = 4.40$, $p < .05$. Schedules O and O− together led to generally, but not reliably ($p > .05$), less responding than did Schedule I. And Schedules O and O− maintained similar low levels of responding.

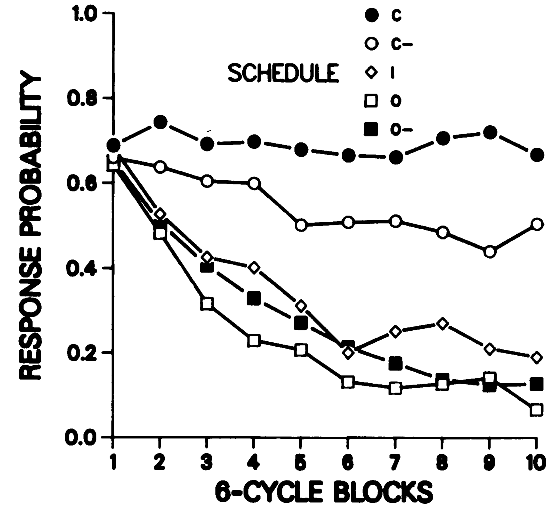


Fig. 1. Mean probability of 48 subjects' telegraph-key responding in successive 6-cycle blocks of training under the five different schedules in Experiment 1. Probability was assessed as the proportion of cycles containing at least one key tap.

Table 2 shows the overall probabilities of responding for each subject under each of the five schedules. As analysis of variance had yielded two statistically significant trends (Schedules C and C− together maintained more responding than did Schedule I; Schedule C maintained more responding than did Schedule C−), individual subjects might show zero, one, or both of these trends. The actual percentages of subjects manifesting zero, one, or both trends were 2%, 40%, and 58%, respectively. This distribution differs significantly from that expected by chance, $\chi^2(2) = 32.46$, $p < .001$, showing that group trends generally reflected the behavior of individual subjects.

Further individual-subject data are shown in Figure 2. This figure depicts the probability of key tapping under each of the five schedules in successive, 12-cycle blocks of training for 3 of the 48 subjects. These subjects were chosen because they demonstrated both (Subject 9M3), one (Subject 9M1), and none (Subject 3F1) of the significant group trends

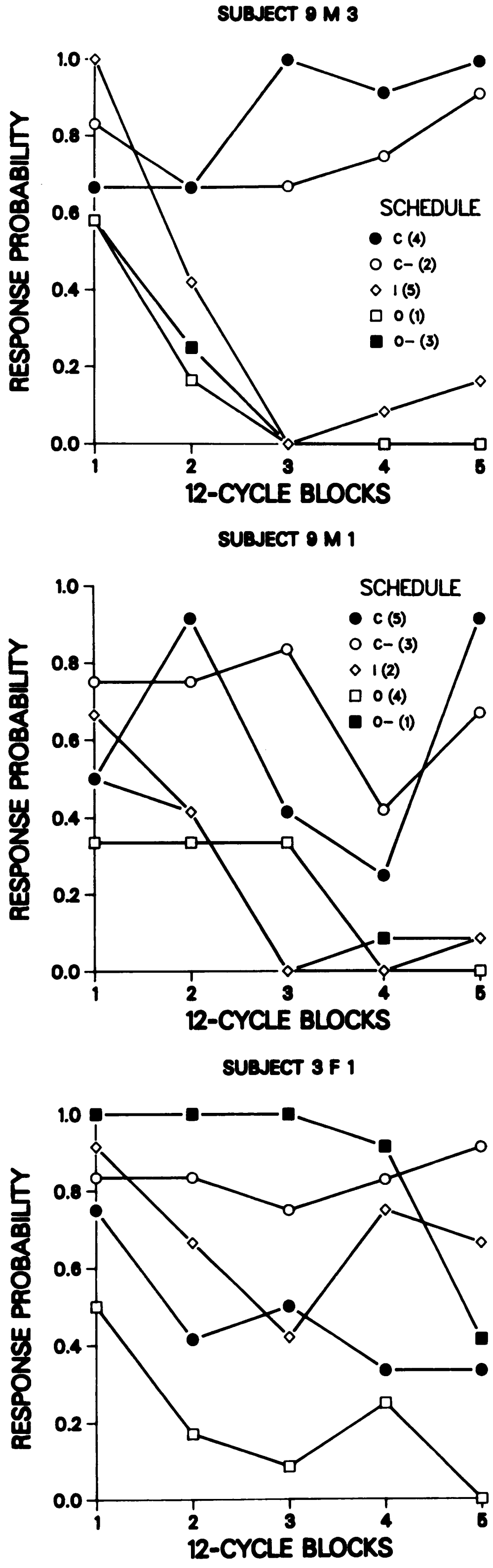
Table 2

Overall response probabilities [p(R)] and causal rating scores (RS) for each subject (S) of each sex in each group (t-s sampling interval) under each schedule of Experiment 1.

			Schedule									
			C		C−		I		O		O−	
t s	Sex	S	p(R)	RS	p(R)	RS	p(R)	RS	p(R)	RS	p(R)	RS
3	F	1	.53	20	.83	0	.68	0	.20	−80	.87	0
3	F	2	.90	70	.80	30	.30	0	.12	−100	.10	−100
3	F	3	.73	60	.90	45	.35	0	.22	−95	.27	−100
3	F	4	.73	100	.37	60	.57	0	.08	20	.43	0
3	F	5	.35	0	.60	35	.08	0	.45	−80	.08	−100
3	F	6	.65	50	.63	50	.28	0	.15	−90	.23	−50
3	F	7	.98	0	.65	45	.48	25	.17	−50	.23	−25
3	F	8	.92	90	.55	80	.20	0	.20	−100	.20	−100
3	M	1	.75	50	.52	50	.38	0	.17	−100	.60	−100
3	M	2	.00	75	.77	−60	.10	0	.13	−89	.05	−99
3	M	3	.27	20	.17	−40	.33	0	.05	−75	.10	−95
3	M	4	.37	0	.07	−66	.25	0	.10	−50	.13	−100
3	M	5	1.00	70	.12	−60	.08	0	.13	−80	.07	−100
3	M	6	.73	−20	.42	−50	.03	−100	.23	−100	.07	−100
3	M	7	.07	−100	.03	−100	.08	−80	.00	−100	.45	−100
3	M	8	.58	50	.50	50	.25	0	.30	−75	.20	−100
6	F	1	.97	80	.72	30	.35	0	.20	−90	.20	−100
6	F	2	.98	70	1.00	50	.50	0	.28	−90	.65	−10
6	F	3	1.00	10	.75	5	.90	0	.23	−90	.43	−90
6	F	4	.22	50	.75	66	.12	0	.10	−50	.67	−100
6	F	5	.03	97	.62	30	.12	0	.13	−45	.08	−100
6	F	6	.92	85	.62	75	.27	0	.52	5	.95	−80
6	F	7	1.00	75	.13	−90	.15	0	.33	−100	.10	−100
6	F	8	.92	60	.57	60	.05	−100	.20	−90	.22	−100
6	M	1	.15	0	.73	20	.28	0	.17	−100	.08	0
6	M	2	1.00	25	.12	−50	.20	0	.33	−100	.13	−100
6	M	3	.80	30	.35	−25	.35	0	.22	−50	.10	−75
6	M	4	.70	−40	.62	30	.85	0	.38	−85	.43	−100
6	M	5	.85	95	.58	66	.72	0	.50	−60	.62	−100
6	M	6	.75	10	.68	−10	.63	0	.65	−100	.65	−100
6	M	7	.78	0	.70	35	.47	0	.18	−90	.20	−90
6	M	8	.47	100	.10	−45	.20	0	.07	−35	.07	−25
9	F	1	.82	50	.53	50	.13	0	.23	−100	.15	−100
9	F	2	.65	30	.20	−50	.27	0	.05	−80	.10	0
9	F	3	.93	75	.95	15	.65	2	.55	−50	.50	−75
9	F	4	.38	10	.42	−20	.25	0	.32	−100	.35	−100
9	F	5	.25	0	.52	−50	.22	0	.17	−100	.00	0
9	F	6	.78	30	.48	20	.13	0	.15	−50	.43	−50
9	F	7	.53	50	.42	50	.25	0	.72	−100	.20	−100
9	F	8	1.00	90	.68	50	.37	0	.27	−96	.18	−100
9	M	1	.60	25	.62	−30	.23	0	.20	−100	.22	−80
9	M	2	1.00	10	.70	25	.38	0	.27	−100	.70	0
9	M	3	.85	20	.77	10	.33	0	.15	−100	.17	−100
9	M	4	.95	80	.85	30	.85	0	.48	−50	.48	−100
9	M	5	.83	90	.72	60	.42	0	.30	0	.37	−80
9	M	6	.70	60	.72	50	.70	0	.33	−100	.23	−90
9	M	7	.93	0	.42	−100	.43	0	.30	−100	.12	−100
9	M	8	.95	75	.30	−75	.48	0	.15	−100	.30	−100

in *overall* response probability. The depicted blocks were increased in size from 6 cycles (Figure 1) to 12 cycles (Figure 2) in order to make the individual functions more orderly to the eye.

Figure 2 shows that, within 24 training cycles, Subject 9M3 came to respond more under Schedules C and C− than under Schedules I, O, and O−. Furthermore, over the last 36 cycles of training, this subject responded



more under Schedule C than under Schedule C−. Like Subject 9M3, Subject 9M1 came to respond more under Schedules C and C− than under Schedules I, O, and O− within the first 24 training cycles; however, Subject 9M1 did not respond consistently more under Schedule C than under Schedule C−. Finally, the behavior of Subject 3F1 was more poorly controlled by the different schedules. As was true of most subjects, relative to Schedule I, Schedule C− increased and Schedule O decreased responding; however, unlike most subjects, relative to Schedule I, Schedule C decreased and Schedule O− increased responding. These uncharacteristic findings might have been due to Schedule O− being the first problem given and to Schedule C being the last problem given. However, scrutiny of Table 2 shows that other subjects (6F1, 9F1, 9M1, 3F6, 3M6) given the five schedules in the same order (see Table 1) nonetheless manifested well controlled schedule performance.

In sum, schedules that promoted response-reinforcer contiguity (C and C−) sustained more operant behavior than did a schedule of response-independent reinforcement (I), even when the contiguity-promoting schedule (C−) entailed a negative correlation between response rate and reinforcement rate. Although similar to the results of Thomas (1981), our data did not show the acquisition of responding under contiguity-promoting schedules. Despite the instruction that not tapping the key might sometimes lead to more points being earned than tapping it and despite the inclusion of two omission schedules, the probability of key tapping exceeded .60 in the first block of six cycles, a level high enough to obscure acquisition even if it occurred.

There also were no notable differences in operant responding among Schedules I, O, and O−. Here, however, key tapping rapidly dropped to very low levels. Thus, a floor effect may have prevented us from observing any differences among these schedules.

←

Fig. 2. Probability of telegraph-key responding in successive 12-cycle blocks of training for Subjects 9M3 (top), 9M1 (middle), and 3F1 (bottom) under the five different schedules in Experiment 1. The ordinal position of each schedule is given in parentheses. (Note that Subjects 9M1 and 3F1 received the five schedules in the same order.)

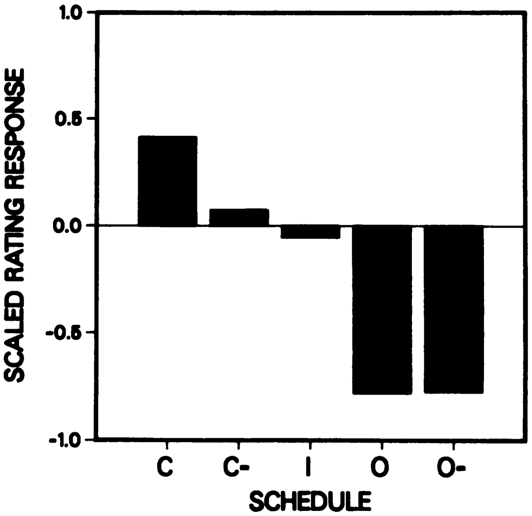


Fig. 3. Mean scaled causal ratings of 48 subjects for the five different schedules in Experiment 1. Scaling was achieved by dividing the subjects' ratings by 100.

Causal Ratings

Figure 3 shows the mean scaled (divided by 100) causal ratings for each of the five schedules. Ratings were moderately positive under Schedule C, slightly positive under Schedule C−, nearest to zero under Schedule I, and similar and highly negative under Schedules O and O−. Analysis of variance revealed that the main effect of schedules was reliable, $F(4, 180) = 115.72$, $p < .001$. The main effect of sampling interval was not significant, nor did this factor interact with the schedules factor. Therefore, Figure 3 does not separately depict ratings for the three different sampling interval groups.

Because the five schedules yielded different causal ratings, additional tests were conducted to clarify the nature of the differences. Schedules C and C− together supported reliably more positive causal ratings than did Schedule I, $F(1, 180) = 23.75$, $p < .001$. Schedule C supported reliably more positive causal ratings than did Schedule C−, $F(1, 180) = 23.46$, $p < .001$. Schedules O and O− together led to reliably more negative causal ratings than did Schedule I, $F(1, 180) = 142.77$, $p < .001$. And Schedules O and O− supported similar, highly negative causal ratings.

Table 2 shows the causal ratings for each subject under each of the five schedules. As analyses of variance had yielded three statistically significant trends (Schedules C and C− together sustained more positive ratings than did Schedule I; Schedule C sustained more positive ratings than did Schedule C−; Schedules O and O− together sustained more negative ratings than did Schedule I), individual subjects might show zero, one, two, or all three of these trends. The actual percentages of subjects manifesting zero, one, two, or all three trends were 0%, 8%, 48%, and 44%, respectively. This distribution is significantly different from that expected by chance, $\chi^2(3) = 55.78$, $p < .001$, again showing that group trends generally reflected the behavior of individual subjects.

Thus, the ratings data confirm and extend the earlier key-tap data. Schedules that promoted response-reinforcer contiguity (C and C−) supported more operant behavior and more positive causal ratings than did a schedule of response-independent reinforcement (I). Like rats, humans responded more when the only consequences were to move reinforcers forward in time and to make reinforcers contiguous with the responses that moved them. This response-enhancing effect of response-reinforcer contiguity was also accompanied by positive causal ratings. Although reduced relative to Schedule C, operant performance and causal ratings were similar under Schedule C−. This reduction could be due to several factors, including fewer response-reinforcer contiguities or the negative response-reinforcer relation of the C− schedule.

Schedules of reinforcement omission (O and O−) resulted in more negative causal ratings than did a schedule of response-independent reinforcement, even though key-tap responding under Schedules O and O− did not differ from Schedule I. This pattern of results strengthens earlier speculation that a floor effect may have prevented our discerning differences in responding among these three schedules. The most obvious reason for subjects' negative ratings under Schedules O and O− is the negative conditional relation and/or molar correlation that these schedules entail. Another, no less plausible, possibility is that Schedules O and O− involve longer response-reinforcer delays for the designated operant than for other behavior patterns. Later discussion will more thoroughly evaluate this relative-contiguity interpretation.

Finally, essentially equivalent operant responding and causal ratings were found with the three sampling intervals that we studied. The range of from 3 to 9 s evidently was not large enough to support measurable differences in behavior.

EXPERIMENT 2

Hineline (1970, Experiment 1) investigated the reinforcing effect of shock delay. Rats were placed on a discrete-trial procedure in which a lever press within the first 8 s of a 20-s trial delayed shock onset from 8 s to 18 s into the trial. With three naive animals, lever pressing was quickly established under this schedule, the probability of a response rising from about .25 in the first session to between .75 and .95 by the 30th session. Responding increased even though there was no probabilistic relationship per 20-s interval between pressing and shock delivery (each 20-s trial entailed one shock, irrespective of lever pressing); nor was there a negative correlation between the rate of responding and the rate of shock delivery (a rarely encountered feature of the procedure was that rats received an extra shock if they pressed the lever between the 8-s and 10-s mark of the trial, thus producing a slight positive correlation).

The present experiment assessed whether human operant behavior is similarly affected by delaying an aversive event. Our adaptation of Hineline's procedure was a free-operant technique, using an outcome-delay (D) schedule that comprised 20 cycles. Each cycle in turn comprised a response time, R*t,* followed by an outcome time, O*t*. If a subject failed to respond within R*t,* a point-loss light was presented at the end of R*t*. If, however, a subject tapped the telegraph key at least once within R*t,* the point-loss light was delayed until the end of O*t,* which began right after the end of R*t*. Thus, a response within R*t* could delay point loss from R*t* to R*t* + O*t*. If outcome delay is reinforcing, we expected subjects to respond with high probability and also to report that key tapping prevented the loss light from occurring, even though, evaluated over whole cycles, there was no conditional relationship between key tapping and light delivery and, evaluated over the entire session, there was no correlation between the rate of key-tap responding and the rate of light presentation.

As a control for chance temporal conjunctions between key tapping and point loss (one not included by Hineline), a response-independent (I) schedule was included in which the point-loss light was always presented at the same time every cycle. Here, we expected much less operant responding; we also expected subjects to report that responses had no effect on the occurrence of the loss light.

If delaying an aversive event is reinforcing, is advancing an aversive event punishing? To find out, we included a third schedule—an outcome advance (A) procedure—in which subjects' key taps during R*t* advanced point loss from the end of O*t* to the end of R*t*. If outcome advance is punishing, we expected least responding in this condition and reports that key tapping caused the loss light to occur.

The trio of procedures described so far (Schedules D, I, and A) were illustrated in connection with an aversive event—point loss. This experiment also addressed the symmetry of results obtained with aversive and appetitive consequences. Thus, individual subjects were given second exposures to Schedules D, I, and A, but here the outcome was a different-colored light correlated with point gain. Our predictions for operant responding under Schedules D and A with point gain were opposite to those with point loss: Subjects should respond most under Schedule A and least under Schedule D. As was the case for outcomes signifying point loss, we expected Schedule A to support reports of response-outcome causation and Schedule D to support reports of response-outcome prevention. And, as was also true for point-loss outcomes, we expected Schedule I to support intermediate levels of operant responding and reports of no relation between response and outcome.

Finally, we again sought to assess whether the extent of temporal movement of outcomes affected operant responding and causal ratings. For different groups of subjects, we set O*t* to 10, 15, or 20 s. We predicted that the longer the outcome time, the greater the extent of outcome advance and delay, and the greater the behavioral effects of Schedules A and D.

METHOD

Subjects and Apparatus

The subjects were 36 research participants like those in Experiment 1. Subjects were randomly assigned to the 10-, 15-, and 20-s outcome time conditions, with the restriction that each contain an equal number of males and females ($n = 6$). The apparatus was the same as that used in Experiment 1.

Procedure

Upon entering the laboratory, subjects were seated at a desk in an experimental room. They were then read instructions similar to those in Experiment 1, except they were told that by responding or by refraining from responding they could *gain* points by getting the green light to *come on,* and they could *avoid losing* points by getting the red light to *stay off.*

Each subject received the outcome-delay (D), response-independent (I), and outcome-advance (A) schedules under both the point-gain and the point-loss conditions. Each problem comprised 20 cycles, and each cycle comprised a response time, R*t,* followed by an outcome time, O*t.* In Schedule D under the point-loss condition, a 0.10-s red point-loss light was presented at the end of R*t* if no key-tap response occurred during R*t.* If a subject tapped the key at least once during R*t,* the point-loss light was delayed until the end of O*t,* which began immediately after R*t.* Thus, the first response within R*t* delayed point loss from R*t* to R*t* + O*t.* Other responses within R*t* and O*t* had no effect on the timing of the outcome light. In Schedule I under the point-loss condition, the red point-loss light was always presented at the end of O*t.* Responses during R*t* and O*t* had no effect on the timing of the outcome light. In Schedule A under the point-loss condition, if no key-tap response occurred during R*t,* the red point-loss light was presented at the end of O*t.* If a subject tapped the key at least once during R*t,* the point-loss light was advanced from the end of O*t* to the end of R*t.* Further responses during R*t* and O*t* had no effect on the timing of the point-loss light.

Under the point-gain condition, the D, I, and A schedules functioned in a similar manner, with one important difference: The 0.10-s outcome light was green instead of red and it signaled point gain instead of point loss. Depending upon the experimental group, O*t* was set to 10, 15, or 20 s. R*t* was set equal to 5 s for all experimental groups.

The six schedules were presented in a quasi-random manner (Table 3). After exposure to each problem, subjects rated the relationship between key tapping and delivery of the point-gain or point-loss light on the same bipolar scale used in Experiment 1. Telegraph-key responding was scored in terms of the number of R*t* intervals out of four in which the subject made at least one key tap. This quotient defined the probability of a recorded response and was collected over five successive blocks. (Again, the response rate results were very similar to the response probability data and are not reported.)

Table 3

Order of administration of each of the schedules of Experiment 2 for subjects numbered 1 through 6.

	Schedule					
	Point gain			Point loss		
Subject	A	I	D	A	I	D
1	6	2	3	5	1	4
2	5	3	1	6	4	2
3	2	5	6	4	3	1
4	3	4	2	1	5	6
5	1	6	4	3	2	5
6	4	1	5	2	6	3

Results and Discussion

Telegraph-Key Responding

Figure 4 shows the mean probability of key tapping under each of the six schedules in successive, four-cycle blocks of training. The top portion of the figure depicts operant performance in the point-gain condition and the bottom portion depicts performance in the point-loss condition. In the first block of training, the probability of responding on the various schedules ranged from .38 to .55; by the final block of training, performance on the different schedules had diverged and ranged from .28 to .60. In general, Schedule A (advance) with point gain and Schedule D (delay) with point loss supported the highest levels of key tapping; responding under these two schedules increased from the first to the last block of training. Schedule D with point gain and Schedule A with point loss generally supported the lowest levels of key tapping; responding under these two schedules tended to decrease as training progressed. And Schedule I with both point gain and point loss generally sustained intermediate levels of key tapping; responding under these two schedules also decreased from the first to the last block of training.

Analyses of variance disclosed that the main effect of blocks of training was statistically significant, $F(4, 132) = 6.98$, $p < .001$. Also significant were the two, two-way interactions of blocks of training by schedules, $F(8, 264) = 3.11$, $p < .01$, and schedules by point gain/loss, $F(2, 66) = 24.93$, $p < .001$, plus the three-way interaction of blocks by schedules by points, $F(8, 264) = 4.08$, $p < .001$. The main effect of outcome time was not significant, nor was the blocks by schedules by points by outcome-time interaction. Therefore, Figure 4 does not separately illustrate responding for the three different *Ot* groups.

Because the overall probabilities of telegraph-key responding depended upon both the schedule and the point gain/loss, additional tests were conducted to clarify the nature of the differences. Within the point-gain condition, Schedule A engendered reliably more responding than did Schedule I, $F(1, 33) = 12.74$, $p < .01$; Schedule D sustained reliably less responding than did Schedule I, $F(1, 33) = 22.67$, $p < .001$. Within the point-loss condition, Schedule A sustained reliably less responding than did Schedule I, $F(1, 33) = 10.35$, $p < .01$; Schedule D engendered reliably more responding than did Schedule I, $F(1, 33) = 17.48$, $p < .001$.

Table 4 shows the overall probabilities of responding for each subject under each of the six schedules. As analyses of variance had yielded four statistically significant trends (for point gain, Schedule A > Schedule I and Schedule D < Schedule I; for point loss, Schedule A < Schedule I and Schedule D > Schedule I), individual subjects might show zero, one, two, three, or all four of these trends. The actual percentages of subjects manifesting zero, one, two, three, or all four of these trends were 0%, 11%, 25%, 50%, and 14%, respectively. This distribution differs reliably from that expected by chance, $\chi^2(4) = 18.89$, $p < .001$, showing that group trends generally reflected the behavior of individual subjects.

Further individual-subject data are shown in Figure 5. This figure depicts the probability of key tapping under each of the six schedules in successive, four-cycle blocks of training for 3 of the 36 subjects. These subjects were chosen because they evidenced four (Subject 10F3), three (Subject 15M5), and one (Subject 20F5) of the significant group trends in *overall* response probability. In the first block of training, Subject 10F3 responded under all six schedules with probabilities equal to or greater than .50; however, over the last two

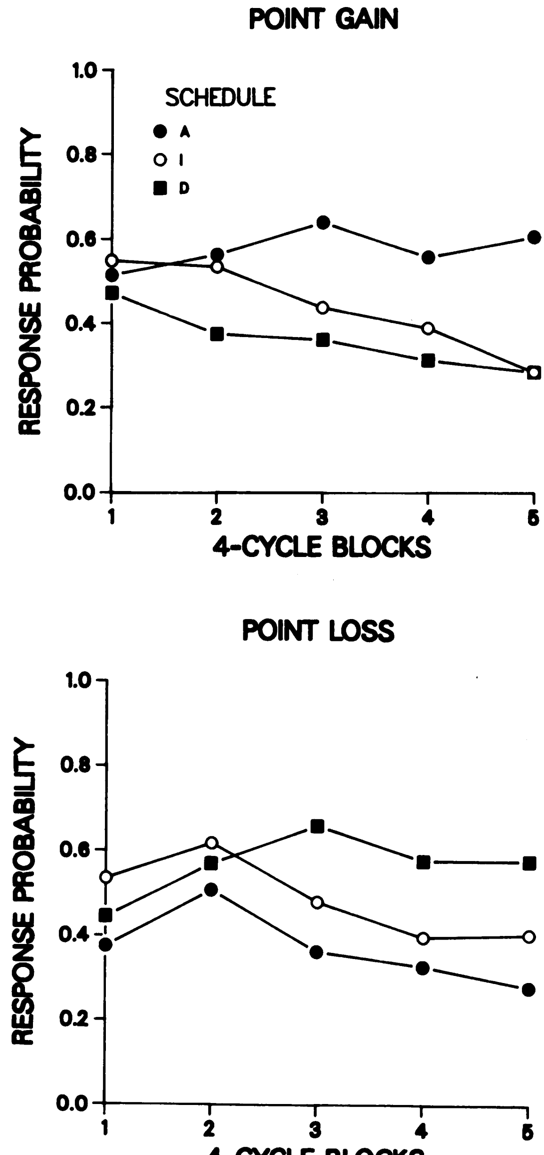


Fig. 4. Top: Mean probability of telegraph-key responding for 36 subjects in successive 4-cycle blocks of training for the point-gain condition under Schedules A, I, and D in Experiment 2. Bottom: Mean probability of telegraph-key responding for the same 36 subjects in successive 4-cycle blocks of training for the point-loss condition under Schedules A, I, and D in Experiment 2.

Table 4

Overall response probabilities [p(R)] and causal rating scores (RS) for each subject (S) of each sex in each group (t-s outcome time) under each schedule of point gain and point loss of Experiment 2.

			Schedule											
			Point gain						Point loss					
			A		I		D		A		I		D	
Ot s	Sex	S	p(R)	RS	p(R)	RS	p(R)	RS	p(R)	RS	p(R)	RS	p(R)	RS
10	F	1	.45	50	.60	0	.15	50	.35	−50	.55	0	.00	−75
10	F	2	1.00	49	.70	0	.95	35	.80	0	.90	72	.65	60
10	F	3	.90	20	.45	0	.40	−20	.20	30	.30	0	.80	−30
10	F	4	.85	60	.20	50	.35	0	.70	−20	.60	−10	.65	−40
10	F	5	.80	30	.45	−10	.20	0	.20	30	.25	0	.65	−40
10	F	6	.50	10	.40	0	.35	−10	.40	5	.45	0	.35	0
10	M	1	.70	30	.55	0	.40	−30	.30	20	.55	0	.40	−40
10	M	2	.40	50	.30	0	.00	0	.40	−50	.70	0	.75	−100
10	M	3	.55	10	.55	0	.10	−20	.35	0	.30	0	.20	−20
10	M	4	.65	0	.20	10	.80	10	.75	0	.75	−10	.75	−40
10	M	5	.60	30	.20	10	.75	10	.45	0	.55	−20	.90	−30
10	M	6	.20	−4	.20	−3	.05	−5	.15	80	.25	0	.40	0
15	F	1	.75	30	.80	0	.40	−80	.30	30	.50	10	.70	−90
15	F	2	.95	10	.80	55	.65	20	.15	0	.80	−20	.95	−50
15	F	3	.65	10	.35	0	.25	−40	.25	20	.15	0	.50	−40
15	F	4	.35	95	.05	20	.35	−50	.45	90	.30	30	.55	−100
15	F	5	.70	20	.75	30	1.00	0	.50	0	.85	−20	.90	−20
15	F	6	.80	60	.65	40	.30	−70	.10	80	.90	−60	.75	0
15	M	1	.45	50	.25	10	.00	−30	.35	40	.80	−50	.00	−40
15	M	2	.65	0	.55	0	.55	0	.20	0	.25	0	.65	0
15	M	3	.55	0	.35	0	.10	0	.45	0	.30	0	.50	−75
15	M	4	.40	0	.50	0	.35	0	.20	0	.55	0	.50	0
15	M	5	.85	70	.50	−30	.70	0	.30	80	.60	30	.85	10
15	M	6	.50	0	.35	0	.40	0	.45	0	.55	0	.70	0
20	F	1	.10	0	.25	0	.10	0	.35	0	.25	0	.20	0
20	F	2	.65	50	.35	0	.20	0	.30	40	.20	0	.55	0
20	F	3	.75	20	.35	−10	.05	−60	.40	0	.55	0	.35	−40
20	F	4	.40	10	.20	0	.35	0	.20	70	.55	0	.30	0
20	F	5	.55	40	.60	0	.75	10	.70	0	.45	0	.65	1
20	F	6	.80	90	.55	0	.20	−100	.35	50	.50	0	.90	0
20	M	1	.10	0	.75	0	.40	−50	.30	−5	.20	0	.60	−15
20	M	2	.25	0	.30	0	.10	−20	.25	65	.40	0	.65	20
20	M	3	.60	0	.40	0	.25	0	.45	0	.45	0	.50	−50
20	M	4	.30	0	.25	0	.00	0	.45	−10	.20	0	.20	−5
20	M	5	.55	90	.45	0	.50	0	.30	40	.50	90	.65	−80
20	M	6	.45	−20	.65	10	.55	−10	.50	0	.55	0	.75	0

blocks of training, responding was principally confined to Schedule A with point gain and to Schedule D with point loss. As acquisition proceeded, Schedule I engendered more responding than Schedule D with point gain and Schedule I engendered more responding than Schedule A with point loss. With point loss, Subject 15M5 responded similarly to Subject 10F3; however, with point gain, Subject 15M5 responded at too high a probability under Schedule D, at least until the final training block. Finally, Subject 20F5 manifested rather unsystematic patterns of behavior under the six schedules.

In sum, the movement in time of environmental outcomes can reinforce and punish human operant behavior. Relative to a response-independent schedule, advancing point gain or delaying point loss strengthened operant responding; relative to a response-independent schedule, delaying point gain or advancing point loss weakened operant responding. The systematic and symmetrical effects of appetitive and aversive outcomes held even though,

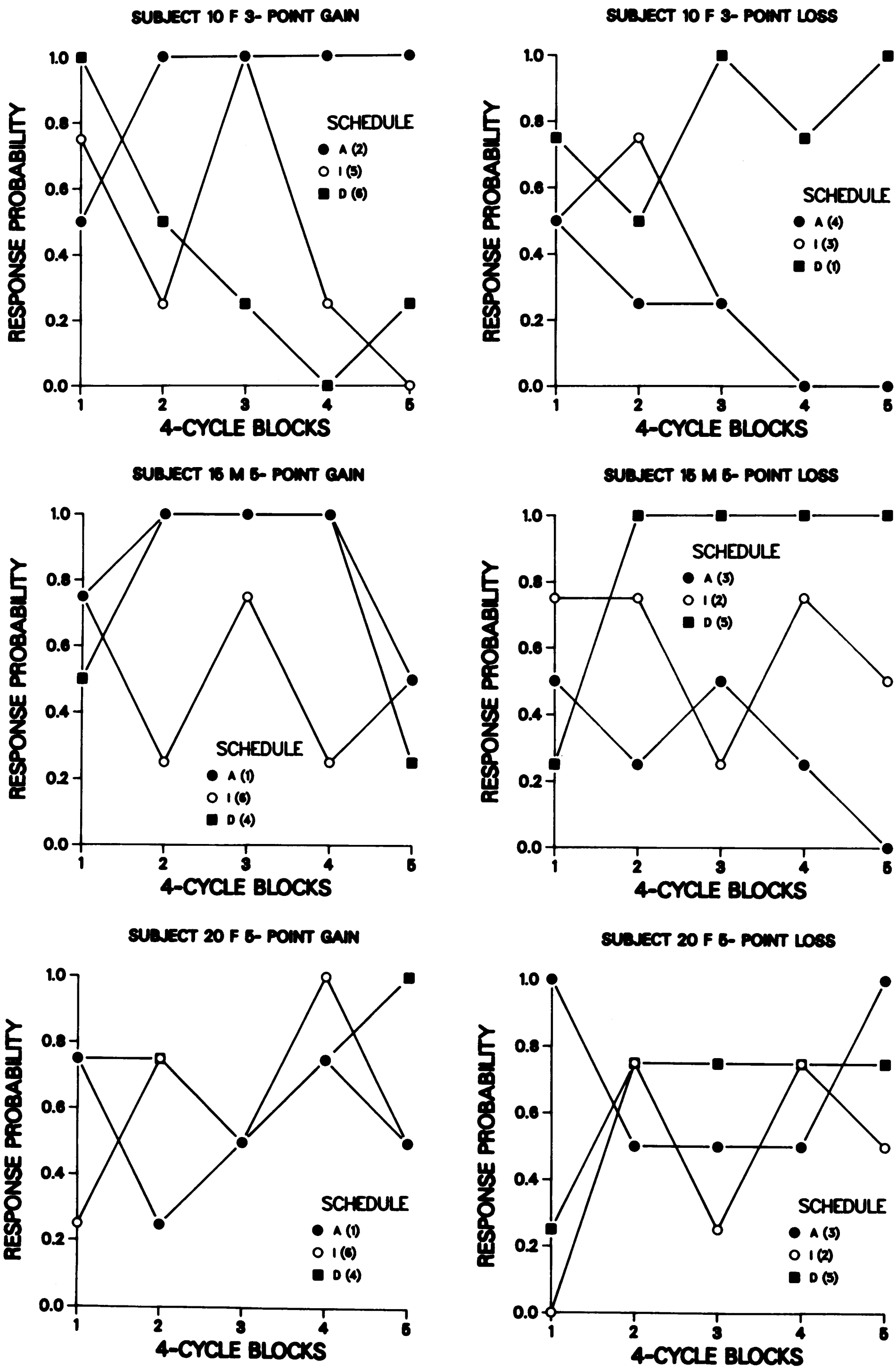


Fig. 5. Probability of telegraph-key responding in successive 4-cycle blocks of training for Subjects 10F3 (top), 15M5 (middle), and 20F5 (bottom) under Schedules A, I, and D in Experiment 2. Data from the point-gain (left) and point-loss (right) conditions are separately depicted. The ordinal position of each schedule is given in parentheses

considered across cycles, responses had no effect on probability of point gain or point loss, nor did changes in the rate of operant responding affect the rate of outcome presentation.

Causal Ratings

Figure 6 shows the mean scaled causal ratings under each of the six schedules for the point-gain and for the point-loss conditions. Ratings under Schedule A were positive, ratings under Schedule I were nearest to zero, and ratings under Schedule D were negative. Also, ratings were more positive in the point-gain condition than in the point-loss condition.

Analyses of variance revealed that the main effects of schedules, $F(2, 66) = 29.79$, $p < .001$, and point gain/loss, $F(1, 33) = 4.51$, $p < .05$, were both significant. The main effect of O*t*, the duration of the delay or advance period, was not significant, nor did it enter into any reliable interactions. Therefore, Figure 6 does not separately show the ratings for the three different O*t* groups.

Because subjects rated the schedules differently, additional tests were performed to clarify the nature of the differences. Separate comparisons were conducted in the point-gain and point-loss conditions to parallel the analyses done earlier on the key-tap data. Within the point-gain condition, Schedule A supported reliably more positive ratings than did Schedule I, $F(1, 33) = 14.98$, $p < .001$; Schedule D produced reliably more negative ratings than did Schedule I, $F(1, 33) = 10.10$, $p < .01$. Within the point-loss condition, Schedule A supported reliably more positive ratings than did Schedule I, $F(1, 33) = 5.99$, $p < .05$; Schedule D produced reliably more negative ratings than did Schedule I, $F(1, 33) = 12.70$, $p < .01$.

Table 4 shows the causal ratings for each subject under each of the six schedules. Because follow-up analyses of variance had yielded two statistically significant trends (Schedule A > Schedule I; Schedule D < Schedule I) that held for both point-gain and point-loss conditions, individual subjects might show zero, one, or both trends when their causal ratings were averaged across both conditions. The actual percentages of subjects manifesting zero, one, or both of these trends were 14%, 42%, and 44%, respectively. This distribution differs reliably from that expected by chance, $\chi^2(2) = 7.72$, $p < .05$, again showing that group trends generally reflected the behavior of individual subjects.

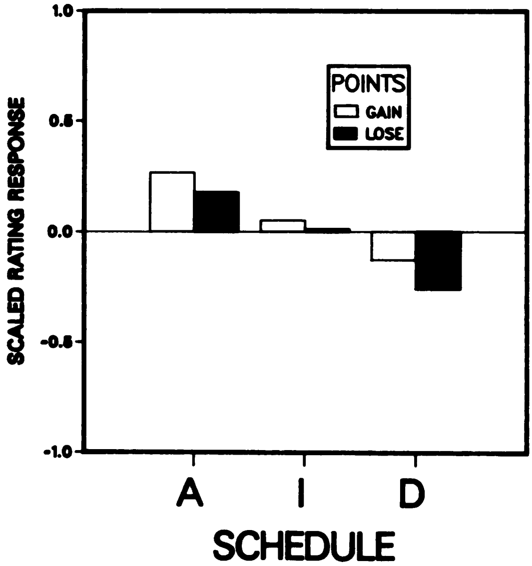


Fig. 6. Mean scaled causal ratings of 36 subjects for Schedules A, I, and D in the point-gain and point-loss conditions of Experiment 2. The scaling was achieved by dividing the subjects' ratings by 100.

Thus, subjects made positive causal ratings of the outcome-advance procedure and they made negative causal ratings of the outcome-delay procedure. These ratings were made even though, considered across whole cycles, neither procedure involved a nonzero conditional relationship or a molar response-outcome correlation. Furthermore, subjects did rather accurately rate their key tapping as having had no effect upon outcome presentation under the noncontingent procedure. Response-outcome contiguity therefore played an important role in subjects' response to and rating of schedules of reinforcement.

Although we confirmed the importance of temporal contiguity in the control of operant behavior, we again failed to find a measurable effect of changing a specific temporal parameter of the task. Here, varying O*t* from 10 to 20 s was without effect. In the prior experiment, changing *t* from 3 to 9 s was without effect. Much greater changes in these independent variables may be necessary before notable behavioral effects are observed.

Finally, subjects rated Schedules A, I, and

D more positively when they involved point gain than when they involved point loss. (Although statistically significant by analysis of variance, only 54% of the subjects showed this trend, a score *not* significantly different from the chance value of 50%.) Some (e.g., Alloy & Abramson, 1979) might offer that this bias reflects a tendency for individuals to claim responsibility for bringing about success, but not to do so for bringing about failure. Rather than an interpretation, this assertion seems to us to be a description of the results. What is in greatest need of clarification is the origin of the bias.

GENERAL DISCUSSION

The present experiments were undertaken to investigate the role of temporal contiguity in subjects' responding to and rating of contingency relations during operant conditioning. Schedules whose sole consequence was moving the time of an inevitable outcome were effective in modifying subjects' key tapping as well as in influencing their later ratings of the prevailing response-outcome contingencies along a -100 to $+100$ prevent–cause scale.

When it advanced the time of an appetitive outcome, key tapping was reinforced and subjects gave positive ratings ("tapping caused the light to occur"). These results held whether outcome advance was accompanied by strict response-reinforcer contiguity (Experiment 1) or not (Experiment 2). When key tapping advanced the time of an aversive outcome, subjects also gave positive ratings; here, however, key tapping was punished by outcome advance (Experiment 2). When it delayed the time of an aversive outcome, key tapping was reinforced and subjects gave negative ratings ("tapping prevented the light from occurring"—Experiment 2). When key tapping delayed the time of an appetitive outcome, subjects also gave negative ratings; here, however, key tapping was punished by outcome delay (Experiment 2).

These results with humans support those with rats (e.g., Hineline, 1970; Thomas, 1981) in showing that operant behavior is sensitive to schedules that determine when but not whether to deliver reinforcers. The human subjects' ratings of the relations arranged by these schedules showed additional behavioral sensitivity to temporal contingencies of reinforcement.

Earlier, we (Chatlosh et al., 1985) conducted a series of experiments examining the operant responding and causal ratings of college students exposed to probabilistic contingencies of reinforcement. There, subjects' operant behavior was strongly influenced by schedules that determined whether to deliver reinforcers, as was true of Hammond's (1980) research with rats. Our humans' causal ratings of the relations arranged by these schedules disclosed further behavioral sensitivity to probabilistic contingencies of reinforcement.

Theoretical Analysis

Demonstrating that both temporal and probabilistic schedules of reinforcement influence humans' responding to and rating of contingency relations does not, of course, tell us exactly what feature(s) of those contingencies is (are) influencing their behavior. One possibility is that temporal contiguity and local probabilistic relationship are *independent* contributors to operant conditioning and causal ratings. (The remainder of the discussion will not focus on molar response-reinforcer correlation as it fared so badly as an account of our subjects' behavior and of the results of other investigators as well.) A more parsimonious proposal is that organisms respond to different contingencies with a *single* mechanism. But is that mechanism time-based or based on the local conditional relationship between response and reinforcer?

Many theorists (e.g., Church, 1969; Gibbon, Berryman, & Thompson, 1974; Hammond, 1980; Seligman et al., 1971) have argued that organisms are principally or exclusively sensitive to the local conditional or probabilistic relationship between response and reinforcer. The concept of conditional relationship is certainly an elegant way of conceptualizing schedules of reinforcement. If all we need do is calculate $p(S^*/R)$ and $p(S^*/\text{no R})$ and subtract the latter conditional probability from the former, then we can simply and precisely classify schedules of reinforcement and perhaps easily identify the behaviorally relevant feature(s) of those schedules.

In order to make these probabilistic calculations, we must first pick some interval of time during which to decide whether a response did or did not occur. However, the choice of that time interval is anything but arbitrary; it critically affects how we classify the schedule (see Thomas, 1983). For instance, consider Schedules A, I, and D of Experiment 2. If we calculate $p(S^*/R)$ and $p(S^*/\text{no } R)$ on a cycle-by-cycle basis, we would conclude that there was no local conditional relation between operant responding and the scheduled outcome because both conditional probabilities equal one and their difference equals zero. However, if we reduce the calculational interval to 5 s (the value of R*t*), then it can be shown that Schedule A would involve a positive conditional relation, Schedule I would involve a zero conditional relation, and Schedule D would involve a negative conditional relation. That there is *some* sampling interval that yields probability-difference scores that jibe with subjects' causal ratings cannot be construed as strong support for this theory; such correspondence may be purely accidental. Without a priori means of specifying a *particular* sampling interval, the many other virtues of the probabilistic approach are seriously compromised (see also Hammond & Paynter, 1983; Thomas, 1983; Watson, 1979).

If we reject probabilistic relations as the basis of our subjects' operant behavior and their causal ratings, then we must assess the merits of temporal contiguity as an acceptable analysis. We must, in particular, confront the main problem that theorists have noted for contiguity formulations—namely, that under probabilistic schedules, operant responding is an inverse function of $p(S^*/\text{no } R)$—(Chatlosh et al., 1985; Hammond, 1980; Rachlin & Baum, 1972). Certainly, increasing the probability of reinforcement in the absence of operant responding cannot increase the delay between operant responses and reinforcers.

We propose to solve this problem by considering the delays of reinforcement after operant responses *and* after types of behavior other that the specified operant (nonoperant responses). We thus define *relative contiguity* as the extent to which the delay of reinforcement after occurrences of the specified operant response (d_o) differs from that after nonoperant responses (d_n): specifically, relative contiguity = $d_n - d_o$. If reinforcers are presented independently of one another, then the delay of reinforcement after any given operant response or any given nonoperant response will be equal and the relative contiguity score of the noncontingent schedule will be zero. If reinforcers follow operant responses with a shorter delay than they follow nonoperant responses (as in the example of the VR 2 schedule described in the introduction), then the relative contiguity score of the schedule will be positive. And if reinforcers follow operant responses with a longer delay than they follow nonoperant responses (as in the case of the O and O− schedules of Experiment 1), then the relative contiguity score of the schedule will be negative. (For more on computing delays, see Hursh & Fantino, 1973, and Moore, 1984.)

We expect that subjects' ratings (along our prevent–cause scale) of the relations arranged by various schedules of reinforcement will be a direct function of the relative contiguity scores of those schedules. We further expect that subjects' operant responding will also be a function of the relative contiguity arranged by various schedules. With appetitive outcomes, responding should increase as relative contiguity increases from negative to positive values; with aversive outcomes, responding should decrease as relative contiguity increases from negative to positive values.

Obviously, the notion of relative contiguity will encompass familiar delay-of-reinforcement effects (Renner, 1964; Tarpy & Sawabini, 1974); increases in the delay between operant and reinforcer are ordinarily accomplished without any scheduled decreases in the delay between nonoperants and the reinforcer. More noteworthy is the fact that the idea of relative contiguity helps us understand why operant responding decreases when $p(S^*/\text{no } R)$ is increased in probabilistic schedules of reinforcement. True, there is no increase in d_o when $p(S^*/\text{no } R)$ is raised; but there is a decrease in d_n. Thus, operant responding should decrease because of a decrease in relative contiguity, $d_n - d_o$.

Our notion of relative contiguity bears considerable resemblance to Fantino's concept of psychological distance to reward (Fantino, 1977; Hursh & Fantino, 1973) and to Herrnstein's formulation of the matching law (Herrnstein, 1970; see also Shull, Spear, & Bryson, 1981). Whereas their accounts were initially addressed to multioperant concurrent schedules of reinforcement, our analysis centers on the single-operant situation. In the multioperant setting, organisms tend to make responses that hasten the delivery of reinforcers. Even though explicit choices among equally effortful responses are not arranged in the single-operant setting, it is quite reasonable to assume that here, too, organisms make moment-by-moment choices among a wide array of possible classes of behavior. Emitting the response with the shortest delay to reinforcement would then correspond with predictions derived from our notion of relative contiguity.

Our account also aspires to understand subjects' ratings of the relations arranged by schedules of reinforcement. Some scale of measurement that fixes a response-independent schedule at zero and ranks other schedules above and below that reference level is clearly preferable to alternative mathematical treatments. Nevertheless, our initial efforts at quantifying relative contiguity (Wasserman, Bhatt, Neunaber, Chatlosh, & Dorfman, 1984; see also Brown & Harris, 1978) should be viewed as preliminary approximations to a full-fledged theory of causal perception and associative learning.

Demonstrating the applicability of relative contiguity to the analysis of *probabilistic* schedules of reinforcement would be of limited value if the notion did not help us understand the effects of *temporal* contingencies of reinforcement, such as those we studied here. Consider Schedule C of Experiment 1. There, operant responses were more likely to be immediately followed by a reinforcer than were nonoperant responses; thus, this schedule involves positive relative contiguity. The same holds true for Schedule C− of Experiment 1, although fewer operant-reinforcer conjunctions per session should tend to make Schedule C− less response-enhancing than Schedule C and less likely to support positive causal ratings.

What of the advance and delay schedules of Experiment 2? In Schedule A, effective operant responses must precede outcomes by between 0 and R*t* s; no such bias for short delays exists for nonoperant responses. Thus, Schedule A entails positive relative contiguity. In Schedule D, effective operant responses cannot precede outcomes by less than O*t* s; no such bias against short delays exists for nonoperant responses. Thus, Schedule D entails negative relative contiguity.

Relative contiguity therefore does help to explain the behavioral effects of the temporal schedules that we studied. The applicability of this notion to still other schedules of reinforcement would appear to be warranted by these initial positive indications.

Relation Between Causal Ratings and Other Behavior

Consider the interrelation between subjects' causal ratings and their operant responding under various schedules of reinforcement. Figure 7 depicts the mean probability of telegraph-key responding for the terminal blocks of Experiment 1 (open circles) and Experiment 2 (filled circles) as a function of subjects' mean scaled causal ratings. The observation periods were the last six *t*-s sampling intervals in Experiment 1 and the last four R*t* intervals in Experiment 2. The five data points of Experiment 1 come from Schedules C, C−, I, O, and O−. The three data points of Experiment 2 were derived in a more complex way. The middle-most point represents the mean rating and response probability scores of Schedule I (data pooled from the point-gain and point-loss procedures). The left-most point represents the mean rating score of Schedule D (data pooled from the point-loss and point-gain procedures), and the mean response probability scores for the point-gain version of Schedule D and the point-loss version of Schedule A. The right-most point represents the mean rating score (point gain plus point loss) for both versions of Schedule A, and the mean response probability scores from the point-gain version of Schedule A pooled with those from the point-loss version of Schedule D. We computed scores in this way to take into account all of the data of Experiment 2 and also to rank order those data with respect to the point-gain procedure of Experiment 1: response probabilities rising with increases in causal ratings.

Figure 7 shows that subjects' ratings of the prevailing schedules were highly correlated ($r = .89$) with their telegraph-key responding under those schedules. This result is consistent with cognitively oriented theories, which posit that subjects' responses to schedules of reinforcement are mediated by subjective representations of those schedules (e.g., Seligman, 1975). We note, however, that subjects' causal ratings *followed* their operant responding under those schedules. The high ratings-response correlation shown in Figure 5 may just as reasonably indicate that subjects' causal ratings of reinforcement schedules arose from their operant responding under those schedules. Alternatively, the high correlation between these dependent variables may merely

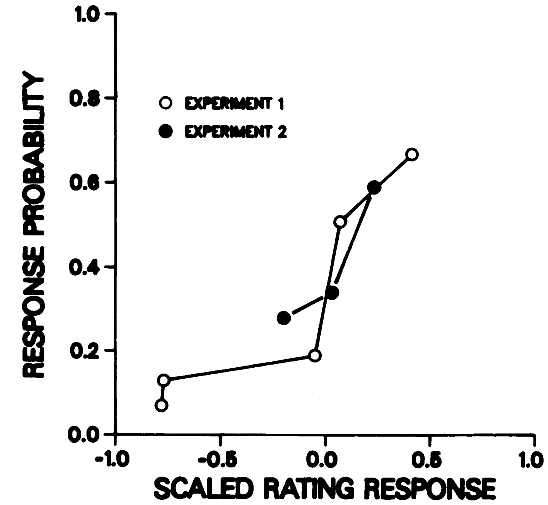


Fig. 7. The relationship between mean scaled causal ratings and mean probability of telegraph-key responding in Experiments 1 and 2. See text for further explication.

show that each class of behavior is highly related to the prevailing schedule without being directly connected with one another.

Psychologists have been grappling with the thorny issue of the relation between verbal reports and action for some time (see Nisbett & Wilson, 1977). For now, we are in no position to pinpoint the link between our subjects' causal ratings and their telegraph-key responding. We are content to find that, at least for the present circumstances, subjects' ratings of the various schedules were consistent with the way they acted under those schedules.

Verbal Reports of Causal Relations

Discussing the significance of verbal reports of the relations arranged by various schedules of reinforcement is difficult for many reasons. First, contingent or causal relations are abstract in nature; relations between objects and events are of greatest pertinence here, not the concrete physical dimensions or properties of the objects and events. Second, since Hume (1739/1962), it has generally been held that causation is fundamentally a psychological phenomenon; our verbal descriptions of the events and relations of the physical world result from our distinguishing and partitioning what may be unitary and continuous entities and processes. And third, the language of causation may have very different meanings to the lay person and to the scientist. Indeed, as we have already seen in discussing three prominent theories of reinforcement contingencies—molar correlation, temporal contiguity, and local probabilistic relation—psychologists themselves disagree as to the key ingredient of causal relations.

Against this backdrop, we began our studies of causal perception (Wasserman et al., 1983) and operant conditioning (Chatlosh et al., 1985) with the hope of making our subjects' task of rating different schedules of reinforcement a relatively easy one. Thus, we anchored our -100 to $+100$ rating scale with the familiar English terms "prevent" and "cause." We believed that virtually all college students had a good understanding of these words. Furthermore, by using these antonyms, we hoped to alert subjects to the bidirectional nature of causal relations: Responding can both bring about and preclude an occurrence. (For more on the bidirectionality of contingency ratings, see Neunaber & Wasserman, in press.) Our college students' highly systematic use of this rating scale in four separate studies has certainly reinforced our choice of this form of verbal report.

Nevertheless, such a simple rating scale may severely limit the numerous features of reinforcement schedules our subjects might conceivably report. Perhaps, like experimental psychologists, our subjects could have reported with other rating scales whether operant responding influenced: (a) the overall rate of reinforcer presentation, (b) the time of reinforcer delivery, or (c) the probability of reinforcer presentation. Their ability or inability to do so might justify experimental inquiry. However, what subjects can be explicitly *trained* to report versus what they would *ordinarily* report after the implicit discrimination training embedded in daily life is a distinction well worth considering when undertaking such a study.

A related and final point of discussion concerns the everyday meanings of the words "prevent" and "cause." Understanding the commonplace sense of terms might help us appreciate just what inter-event relations occasion their usage (Zuriff, 1985). The verb "to prevent" refers to the result of anticipatory action; acting prior to some event may either preclude or hinder its occurrence. Synonyms for the first meaning include: obviate, forbid, rule out, avoid, and nullify. Synonyms for the second meaning include: retard, stay, slow, hamper, and delay. Yet, if we regard the complete removal of an event as essentially equivalent to its infinite postponement, "to prevent" may mean to delay an event. The size of the resulting delay may be relatively short (as in the governor granting a convicted murderer a stay of execution) or relatively long (as in the rerouting of a highway forestalling the destruction of a wildlife refuge).

Time does not at first appear to be so central to the meaning of the verb "to cause," which generally means to produce. Synonyms here include: make, originate, bring about, generate, and provoke. Yet, here too, the word is sometimes given temporal meaning, as in to hasten. Synonyms for this second meaning include: precipitate, accelerate, expedite, and advance. Again, if we regard the production of an event as moving it forward in time from an infinite delay, "to cause" may mean to advance an event. The size of the resulting advance may be relatively short (as when a child's mealtime is moved forward because of persistent pestering) or relatively long (as when a demolition team destroys a gradually decaying building).

Although the present semantic analysis does not prove that time is the critical dimension of causal relations, we believe that it complements and supports our earlier experimental and theoretical analyses. We suggest that a full understanding of causal perception and associative learning may well incorporate familiar conditioning results and concepts as well as less conventional considerations of verbal behavior and linguistics. A good point to begin such studies is by giving subjects probabilistic and temporal contingencies of reinforcement and then asking them to rate those contingencies along both temporal and nontemporal semantic dimensions.

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