Memory & Cognition
1994, 22 (2), 243-248

Influence of the cost of responding on human causality judgments

PHIL REED
University College London, London, England

In three experiments, the effect of costs associated with responding on judgments of the causal effectiveness of the response was examined. In Experiment 1, the temporal interval between outcomes was matched on a variable interval (VI) and a variable ratio (VR) schedule. When each response was made at some "cost," and outcomes represented some "gain" for the subject, the rating of causal effectiveness for responses was higher on the VR than on the VI schedule. This relationship was absent when the outcome was a triangle flash. In Experiment 2, the number of responses required per outcome on a VI and a VR schedule were matched, and responses on the VR schedule were rated as more causally effective. In Experiment 3, a VI-to-VR yoking procedure was used. With minimal response costs, judgments were similar on the VI and VR schedules, but with greater response costs, responses performed on the VR schedule were rated as more causally effective than those emitted on the VI schedule.

It has been suggested that the contingency or schedule that relates a response to its consequence is a fundamental determinant of the behavior that is observed during exposure to that schedule (e.g., Morse & Kelleher, 1970; Nevin, 1979). Different schedules of reinforcement promote markedly different patterns of responding in nonhumans (e.g., Ferster & Skinner, 1957). In addition, schedules have been noted to modulate basic behavioral processes such as positive and negative conditioned suppression (Blackman, 1968), reinforcer devaluation (Adams, 1982), and signaled reward effects (Reed, Schachtman, & Hall, 1988). Given the seemingly ubiquitous influence of schedules of reinforcement on behavior, coupled with the recent interest in the influence of the contingency between response and outcome on human judgments of causation, it would appear sensible to examine the role of schedules relating responses to outcomes in human judgments of causal effectiveness.

There are reasons to expect that various schedules relating responses to outcomes might well differ in the influence that they have over the judgments of the causal effectiveness of a response performed during exposure to that schedule. Many of the factors that appear to influence the course of conditioning have been observed to influence humans' judgment of causal efficacy (Alloy & Abramson, 1979; Chapman & Robbins, 1990; Shanks & Dickinson, 1987; Wasserman, 1990). Evidence for this functional equivalence has been provided from a variety of sources, most notably in relation to the influence of both the contiguity and the contingency between response and outcome (e.g., Shanks, Pearson, & Dickinson, 1989; Wasserman & Neunaber, 1986). For example, judgment of the causal effectiveness of a response is sensitive to the contingency between the emission of a response and the occurrence of an outcome: By holding constant the probability that a response will be followed by an outcome, but increasing the probability that the same outcome will occur in the absence of a response, the rating of the causal effectiveness of that response declines (Dickinson & Shanks, 1985).

On the basis of the results of studies of animal conditioning, Dickinson (1985, 1989; see also Roberts, Tarpy, & Lea, 1984) has suggested that, in nonhumans, the perception of the causal efficacy of a response is lower on a variable interval (VI) schedule than it is on a variable ratio (VR) schedule. Dickinson (1985) argued that because the rate of reinforcement generated by an interval schedule is less sensitive to variations in response rate than is the rate of reinforcement generated by a ratio schedule—that is, increases in response rate produce increases in reinforcement rate on a ratio schedule but do not do so to the same degree on an interval schedule—a subject may assess the causal effectiveness of a response as being lower on an interval schedule than on a ratio schedule. A number of studies have provided data that are, at least, consistent with this view (e.g., Adams, 1982; Roberts et al., 1984).

An initial investigation of the influence of different schedules on the judgment of causal effectiveness indicated that the level of causal effectiveness attributed to a response emitted during exposure to a VR schedule yoked to a VI schedule in terms of responses required per outcome was low (Reed, 1993)—a pattern of results opposite from that predicted on the basis of animal conditioning experiments (e.g., Dickinson, 1985). However,

I would like to thank Lisa Osborne for comments on previous research.
Requests for reprints should be addressed to P. Reed, Department of Psychology, University College London, Gower Street, London WC1 6BT, U.K.

—*Accepted by previous editor, Margaret Jean Intons-Peterson*

these results do not necessarily invalidate the analysis given of schedule performance by Dickinson (1985), as there were a number of important differences between the procedure adopted by Reed (1993) and those for which Dickinson's view was formulated. For example, it is not clear in what sense the outcome (a flash of a triangle displayed on a computer screen) used in the study conducted by Reed (1993) could be equated to a reinforcer in studies of free-operant conditioning; a schedule that relates a response to an outcome is not necessarily a reinforcement schedule, because there may be no reinforcement involved. Further, there were no obvious costs involved in the subject's making a response (pressing a key on the computer keyboard), a factor that has been implicated in influencing performance on free-operant schedules of reinforcement (e.g., Lea, 1979). The present series of studies was an attempt to address the role of response cost in ratings of causal effectiveness.

EXPERIMENT 1

The initial experiment compared the rating of the causal effectiveness of a response performed on a VI and a VR schedule in which the temporal distributions of outcomes were equated. The time taken to obtain a reinforcer or an outcome on the master VR schedule became the interval requirement for the subsequent VI schedule. For one group of subjects, the procedure previously adopted by Reed (1993) was used; the subjects were asked to rate the effectiveness of a response in causing a triangle to flash on a computer screen. For a second group of subjects, an attempt was made to reproduce some of the factors that might contribute to the production of a *reinforcement* schedule, as opposed to the *outcome* schedule used for the first group of subjects. This was attempted in the context of a game in which the subject had to earn "money," each response was made at a certain "cost" to the subject, and the outcomes consisted of a "gain" for the subject. The purpose behind the initial experiment was, thus, to investigate the effect that the introduction of costs for responding, and an outcome that was in some manner advantageous for the subject, would have on causal attribution. If theories derived from animal conditioning can be applied to human causality judgments, then ratings of causal efficacy of responses emitted during exposure to the VR schedule would be greater than those of responses emitted during exposure to the VI schedule.

Method

Subjects. Twenty-six subjects were recruited (12 female and 14 male). All the subjects were volunteers, and they were not paid for their participation. The subjects had an age range of 19 to 32 years.

Apparatus. The experiment was conducted with the subject sitting at a table with a BBC computer that controlled a video display screen (24 cm wide × 17 cm high). The screen was approximately 50 cm in front of the subject. The subjects could respond to the instructions given to them on the video screen via the computer keyboard in front of them.

Procedure. At the start of the experiment, the subjects were given instructions regarding the nature of the task (described by Shanks et al., 1989, but slightly modified for the two different conditions) on the video screen. They were informed that they were to press the space bar of the computer keyboard and try to make an event happen on the screen (a triangle flash for Group Trig, and the addition of some money to a sum total displayed on the screen for Group Cost). The subjects were informed that they would experience two different conditions, each lasting for approximately 4 min. They were also told that after the condition was over they would be asked to give a rating of how effective the response was in producing the event on the screen. This rating was to be on a scale between 0 (the response was not effective at all in producing an outcome) and 100 (the response was always effective in producing an outcome).

The subjects in each group then experienced the two schedule conditions. The schedule conditions were identical in the two groups. During the first condition, the subjects responded (pressed the space bar of the computer) on a VR-8 schedule (range, 1–16). The time taken to complete each successive ratio (i.e., the time taken to make the triangle flash or receive the first investment return) was recorded. These intervals were then used as the requirement for each successive interval for the corresponding triangle flash or investment return in the yoked VI condition. In this manner the temporal distribution of outcomes was equated in the two conditions. Each of the conditions was presented for 4 min.

The groups differed in two respects. In Group Trig, responses to the space bar produced a triangle flash according to the above schedules, with no other programmed contingencies. In Group Cost, each response to the space bar subtracted £100 from a total amount of money displayed on the screen (initially £20,000). An outcome was defined as the addition of £1,000 to the total displayed on the screen.

Results and Discussion

The rate of response to the space bar, the number of outcomes received per minute, the probability of an outcome following a response, and the judgments made by the subjects regarding the causal effectiveness of a response emitted during exposure to the two conditions are displayed in Table 1.

Inspection of the response rate data shows that the subjects in both groups responded faster in the VI than in the VR condition. A two-factor analysis of variance (ANOVA) with group and schedule as factors revealed a main effect of schedule [$F(1,24) = 9.98$, $MS_e = 5{,}508.90$, $p < .01$], but no other significant effects. The number of outcomes obtained was necessarily the same in both the VI and VR conditions, and this meant that the probability of an outcome following a response was higher in the VR than in the VI condition in both groups. A two-factor ANOVA (group × schedule) revealed a main effect of schedule [$F(1,24) = 16.63$, $MS_e = 0.005$, $p < .001$], but there were no other significant main effects or interactions.

Table 1
Mean Response Rates per Minute, Outcomes Obtained per Minute, and Outcomes per Response and Judgment of Causal Efficacy for the VR and VI Conditions in Experiment 1

	Group Trig		Group Cost	
	VI	VR	VI	VR
Responses/min	105.98	51.39	151.14	75.69
Outcomes/min	5.98	5.98	8.85	8.85
Outcomes/response	0.07	0.11	0.08	0.12
Judgment	19.54	15.84	20.85	46.92

The subjects in the two groups rated the causal efficacy of the responses on the two schedules differently. The subjects in Group Trig rated responses performed during exposure to the VI schedule as slightly more effective in producing an outcome than responses performed during exposure to the VR schedule. The subjects in Group Cost rated responses emitted during exposure to the VR schedule as more effective in producing an outcome than responses emitted during exposure to the VI schedule. A two-factor ANOVA (group × schedule) revealed a significant interaction between group and schedule [$F(1,24) = 9.27$, $MS_e = 367.56$, $p < .01$]. Simple effect analyses of schedule for each group revealed that there was no difference between the responses emitted on the two schedules in Group Trig ($F < 1$), but that for Group Cost, the rating of responses emitted on the VR schedule was significantly greater than the rating for responses on the VI schedule [$F(1,24) = 13.26$, $MS_e = 367.56$, $p < .01$].

The present results indicate that when a response is emitted at some "cost," and outcomes represent some "gain," responses are rated as more causally effective when emitted on a VR than on a VI schedule. The findings from Group Cost conform to those predicted on the basis of theories derived from studies of animal conditioning. It should be noted, however, that the actual probability of a response producing an outcome was greater in the VR condition than in the VI condition; this difference in itself may have been responsible for the present result obtained in Group Cost.

EXPERIMENT 2

Although the initial experiment equated the temporal distribution of outcomes across the VI and VR conditions, the obtained probability of an outcome following a response on the two schedules differed. To further explore whether the introduction of costs and gains into the procedure influenced subjects' evaluations of the causal effectiveness of responses, the second experiment was an examination of the effect on causal judgments of the efficacy of a response emitted during exposure to either a VI or a VR schedule when the probability of an outcome following a response was equated across the two schedules. To this end, subjects first performed according to a VI schedule, in which the number of responses emitted for each successive outcome was the number required for each successive outcome in a subsequent VR condition. When a similar experiment was conducted with responses to the space bar producing a flash of the triangle (as in Experiment 1), responses in the VI condition were rated as more causally effective than those in the VR condition, despite the actual probabilities of the outcomes following a response being equal in the two schedules (Reed, 1993). Should the introduction of costs and gains into the procedure alter the perceived causal efficacy of the response, as was apparently the case during Experiment 1, the previous result obtained by Reed (1993) should also be reversed: Responses in the VR condition should be rated as more causally effective than those in the VI condition.

Method

Subjects and Apparatus. Sixteen subjects (10 female and 6 male), with an age range of 19 to 25 years, were recruited as described in Experiment 1. The apparatus was that described in Experiment 1.

Procedure. The subjects were given the same instructions as were the subjects in Experiment 1 for the money condition. They were then exposed to the two different schedules. In the first schedule condition, the subjects responded on a VI 20-sec schedule (range, 1-40 sec), and in the second schedule condition they responded on a yoked VR schedule. The value of the VR component was yoked to the number of responses emitted by the subject in completion of the VI condition. Thus, if a subject emitted 10 responses during the first interval and 5 responses during the second interval set up by the VI condition, then the first ratio in the VR condition would be 10 responses and the second would be 5 responses. Thus, the probability that a response would be followed by an outcome was equated across the two conditions. The VI component lasted for 4 min, and the VR component lasted until the subject had obtained all the investment returns available as a result of the yoking procedure (i.e., the number of outcomes was the same in the two conditions). The subjects performed a judgment of the causal effectiveness of the response (investment) after each condition had ended.

Results and Discussion

The rate of response to the space bar, the number of outcomes received per minute, the probability of an outcome following a response, and the judgments made by the subjects regarding the causal effectiveness of responses emitted during exposure to the two conditions are displayed in Table 2. Inspection of the data shows that the subjects responded faster in the VR than in the VI condition. A matched t test conducted on these data revealed a statistically significant difference between the conditions [$t(15) = 4.09$, $p < .01$]. There was a greater number of outcomes obtained per minute in the VR than in the VI condition [$t(15) = 4.49$, $p < .001$]. The probability of an outcome following a response was necessarily the same in both the VI and VR conditions.

The subjects rated actions performed during exposure to the VR schedule as being more effective in producing an outcome than actions performed during exposure to the VI schedule. A t test conducted on the data for all of the subjects revealed a significant difference between the rating scores for the two conditions [$t(15) = 4.81$, $p < .001$].

The above pattern of results confirms that when there are "costs" to responding and "benefits" associated with the outcome, responses emitted on a VR schedule are rated as more causally effective than those emitted on a VI schedule. This result was obtained despite the fact that

Table 2
Mean Response Rates per Minute, Outcomes Obtained per Minute, and Outcomes per Response and Judgment of Causal Efficacy for the VR and VI Conditions in Experiment 2

	Condition	
	VI	VR
Responses/min	16.20	56.51
Outcomes/min	1.89	6.61
Outcomes/response	0.13	0.13
Judgment	32.06	54.31

the probability of a response preceding an outcome was equal in both conditions.

EXPERIMENT 3

The final experiment was a further assessment of the view that the difference between the investment game and the triangle flash outcome procedure responsible for the production of different ratings of causal effectiveness is that, in the former, responses are emitted at some cost. To test this view, judgments of the causal effectiveness of responses on pairs of yoked VI and VR schedules were studied. Each of the schedules in a pair of yoked schedules was equated for the probability that an outcome would follow a response. In one pair of conditions, a response had a minimal cost. In another pair of schedules, the response cost a lot. If the "cost" of responding is a factor in influencing judgments of causal efficacy, then the greater the cost, the more likely it is that subjects will judge responses emitted on a VR schedule as more causally effective in producing an outcome than those emitted on a VI schedule.

Method

Subjects and Apparatus. Thirty-two subjects (20 female and 12 male), with an age range of 19 to 33 years, were recruited as described in Experiment 1. The apparatus was that described in Experiment 1.

Procedure. The subjects were divided into two groups ($n = 16$). Both groups were given the same instructions that were given to Group Money in Experiment 1. Both groups were then exposed to two different conditions, which were comprised of a yoked pair of VI and VR schedules. The yoking procedure was as described in Experiment 2. The conditions in each group differed by virtue of the amount of money that would be subtracted from the investment fund for each response. For Group Low, the amount subtracted from the total for each response was £1; for Group High it was £100. All other aspects of the experiment were as described in Experiment 2.

Results and Discussion

The rate of response to the space bar, the number of outcomes received per minute, the probability of an outcome following a response, and the mean ratings of the causal effectiveness of a response made by the subjects in both groups in the two schedule conditions are displayed in Table 3. Inspection of the response rates reveals that the subjects in Group Low responded faster in general than those in Group High. In both groups, the subjects responded faster during the VR schedule condition than during the VI schedule condition. These data were analyzed by means of a two-factor ANOVA (group × schedule) that revealed statistically significant main effects of group [$F(1,30) = 20.25$, $MS_e = 18{,}939.86$, $p < .001$] and schedule [$F(1,30) = 43.30$, $MS_e = 1{,}639.66$, $p < .001$], and a statistically significant interaction between the factors [$F(1,30) = 19.17$, $MS_e = 1{,}639.66$, $p < .001$]. The subjects obtained more outcomes per minute in the VR schedule condition than in the corresponding VI schedule condition in both groups. A two-factor ANOVA (schedule × group) revealed a statistically significant main effect of schedule [$F(1,30) = 24.63$, $MS_e = 5.21$, $p < .001$], but no other statistically significant effects ($ps > .09$). The probability of an outcome per response was necessarily the same in each of the yoked pairs of VI and VR schedules. This probability was higher in Group High than in Group Low. A t test conducted on the probability that an outcome would follow a response revealed a significant difference between the groups [$t(30) = 2.93$, $p < .01$].

Table 3
Mean Response Rates per Minute, Outcomes Obtained per Minute, and Outcomes per Response and Judgment of Causal Efficacy for the VI and VR Conditions at Each of the Response Cost Levels in Experiment 3

	Group Low		Group High	
	VI	VR	VI	VR
Responses/min	143.98	254.92	33.47	55.75
Outcomes/min	2.63	5.87	2.08	5.00
Outcomes/response	0.04	0.04	0.10	0.10
Judgment	44.75	44.69	31.88	46.00

Inspection of the subjects' ratings of causal efficacy reveals that the Group Low subjects rated responses emitted during exposure to the two schedules as equally causally effective. In Group High, however, responses emitted during exposure to the VR schedule were rated as more effective than those emitted during exposure to the VI condition. A two-factor ANOVA (group × schedule) conducted on these data revealed a significant interaction between the two factors [$F(1,30) = 4.72$, $MS_e = 170.68$, $p < .05$]. Subsequent simple effects revealed that there was no significant difference between the schedules in Group Low ($F < 1$), but that the two schedules differed significantly in Group High [$F(1,30) = 9.35$, $MS_e = 170.68$, $p < .05$].

In the present study, responses emitted on a VR schedule were rated as similarly causally effective as those on a VI schedule when the response had a minimal cost. However, as the cost of a response rose, responses on the VR schedule were rated as more causally effective than those on the VI schedule. This is consistent with the suggestion that response cost is responsible for the difference obtained in the effect of schedules on ratings of causal effectiveness in the triangle flash and investment game procedures.

GENERAL DISCUSSION

In the present experiments, the influence of various contingencies on human judgments of causation was examined. The primary aim was to examine if the "cost" of a response had an influence on the perception of causal efficacy of responses emitted during exposure to those schedules. The relationship between judgments of causal effectiveness of responses emitted during exposure to a VI and a VR schedule was altered if "costs" for responding and "gains" for obtaining an outcome (within the context of an investment game) were introduced into

schedules relating responses to outcomes with the same parameters but lacking apparent costs and gains. The higher rating of causal efficacy given to responses emitted during exposure to a VR schedule than to a VI schedule with costs and gains was confirmed during Experiment 2; this result was obtained despite the fact that the probabilities of an outcome following a response on a VR and a VI schedule were equated. In Experiment 3, it was noted that increasing the cost of a response produced higher ratings of causal effectiveness of responses emitted on a VR schedule than those on a VI schedule. This suggests that response cost is an important determinant of the manner in which causal attributions are made by humans.

With respect to the influence of the schedule's relating response to outcome on causal attribution, the present results appear to conform to the predictions made by Dickinson (1985), which were based on the interpretation of response rate differences between VI and VR schedules in nonhumans. It appears as if the presence of costs and gains introduces factors that provoke the operation of a different, overriding, or additional set of mechanisms in the estimation of causal effectiveness than when those costs are not present.

Before further discussion of the processes responsible for the different ratings of causal effectiveness of responses on schedules in which costs are, or are not, present, it should be noted that, in the present experiments, the relationship between rates of response (i.e., pressing the space bar) and the operative schedule did not conform to that usually found in response rates of nonhumans (e.g., Peele, Casey, & Silberberg, 1984; Zuriff, 1970): There was no consistent difference in the rates of response on the VI compared with the VR schedule. This fact may be explained in that only one session of training was given with the present task, and such response rate differences do not usually emerge in nonhuman conditioning procedures until a number of sessions have been experienced (see Ferster & Skinner, 1957; Wearden & Clark, 1988). It might be noted that, over time, response rate differences do emerge between VR and VI schedules when the procedures described in the present report are used (Reed, 1994). However, it is apparent from the present data that a difference between the judgment of causal efficacy of responses on the various schedules studied was established by one exposure to the schedule.

In order to explain the previously obtained higher ratings of responses performed according to a VI schedule (see also Experiment 1), it was assumed by Reed (1992, 1993) that subjects perform successive presses of the space bar with a variety of interresponse intervals. Due to the temporal nature of a VI schedule, an outcome is increasingly likely to follow a response as the interresponse interval becomes longer. Given this, an interval-based rule may tend to produce relatively large numbers of outcomes contingent upon a response that is made in temporal isolation from other responses (e.g., Peele et al., 1984). In contrast, the VR rule does not selectively tend to produce outcomes after temporally separated responses. Thus, on a VR schedule, it is equally probable that a subject may have been responding a lot or a little on the space bar prior to the triangle flash. A response performed in temporal isolation may be perceived to be more causally effective, because the subject may make a judgment that one response is sufficient to produce an outcome when that response was temporally isolated, but may assume that a number of responses are required for an outcome if they are performed together immediately prior to an outcome. This explanation will not do, however, to explain the ratings of causal effectiveness when costs and gains are introduced into the procedure.

The present studies were designed only to demonstrate that the addition of costs for responding altered judgments of causal efficacy of responses emitted on VI and VR schedules from those when no costs were apparent and, hence, speculation on the mechanisms responsible for this effect may be unwise. Nevertheless, a tentative suggestion may be put forth to explain the action of costs of causal attribution. It may be that the addition of costs focuses attention on the total number of responses emitted during a session, and increases the sensitivity to the overall relationship between responding and outcomes. If this were the case, then the processes of causal attribution put forth by Dickinson (1985) to explain the difference between VR and VI schedules may exert an influence.

REFERENCES

ADAMS, C. D. (1982). Variations in the sensitivity of instrumental responding to reinforcer devaluation. *Quarterly Journal of Experimental Psychology*, **34B**, 77-98.

ALLOY, L. B., & ABRAMSON, L. Y. (1979). Judgment of contingency in depressed and non-depressed students: Sadder but wiser? *Journal of Experimental Psychology: General*, **108**, 441-485.

BLACKMAN, D. E. (1968). Response rate, reinforcement frequency, and conditioned suppression. *Journal of the Experimental Analysis of Behavior*, **11**, 503-516.

CHAPMAN, G. B., & ROBBINS, S. J. (1990). Cue interaction in human contingency judgment. *Memory & Cognition*, **18**, 537-545.

DICKINSON, A. (1985). Actions and habits: The development of behavioural autonomy. *Philosophical Transactions of the Royal Society of London: Series B*, **308**, 67-78.

DICKINSON, A. (1989). Expectancy theory in animal conditioning. In S. B. Klein & R. R. Mowrer (Eds.), *Contemporary learning theories: Vol. 1. Pavlovian conditioning and the status of traditional learning theory* (pp. 279-308). Hillsdale, NJ: Erlbaum.

DICKINSON, A., & SHANKS, D. R. (1985). Animal conditioning and human causality judgement. In L.-G. Nilsson & T. Archer (Eds.), *Perspectives on learning and memory* (pp. 167-191). Hillsdale, NJ: Erlbaum.

FERSTER, C. B., & SKINNER, B. F. (1957). *Schedules of reinforcement*. New York: Appleton-Century-Crofts.

LEA, S. E. G. (1979). Foraging and reinforcement schedules in the pigeon: Optimal and non-optimal aspects of choice. *Animal Behavior*, **27**, 875-886.

MORSE, W. H., & KELLEHER, R. T. (1970). Schedules as fundamental determinants of behavior. In W. N. Schoenfeld (Ed.), *The theory of reinforcement schedules* (pp. 139-185). New York: Appleton-Century-Crofts.

NEVIN, J. A. (1979). Reinforcement schedules and response strength. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour: Vol 1. Reinforcement and the organization of behaviour* (pp. 117-158). Chichester, U.K.: Wiley.

PEELE, D. B., CASEY, J., & SILBERBERG, A. (1984). Primacy of interresponse-time reinforcement in accounting for rates under variable-

ratio and variable-interval schedules. *Journal of Experimental Psychology: Animal Behavior Processes*, **10**, 149-167.

REED, P. (1992). Effect of local context of responding on human judgment of causality. *Memory & Cognition*, **20**, 573-579.

REED, P. (1993). Influence of schedule of outcome presentation on human judgments of causality. *Quarterly Journal of Experimental Psychology*, **46A**, 327-345.

REED, P. (1994). *Causality ratings on variable-ratio and variable-interval schedules of reinforcement*. Manuscript submitted for publication.

REED, P., SCHACHTMAN, T. R., & HALL, G. (1988). Overshadowing and potentiation of instrumental responding in rats as a function of the schedule of reinforcement. *Learning & Motivation*, **19**, 13-30.

ROBERTS, R. E., TARPY, R. M., & LEA, S. E. G. (1984). Stimulus response overshadowing: Effect of signalled reward on instrumental responding as measured by response rate and resistance to change. *Journal of Experimental Psychology: Animal Behavior Processes*, **10**, 244-255.

SHANKS, D. R., & DICKINSON, A. (1987). Associative accounts of causality judgment. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 21, pp. 229-261). London: Academic Press.

SHANKS, D. R., PEARSON, S. M., & DICKINSON, A. (1989). Temporal contiguity and the judgement of causality by human subjects. *Quarterly Journal of Experimental Psychology*, **41B**, 139-159.

WASSERMAN, E. A. (1990). Detecting response-outcome relations: Toward an understanding of the causal texture of the environment. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 26, pp. 27-82). London: Academic Press.

WASSERMAN, E. A., & NEUNABER, D. J. (1986). College students' responding to and rating of contingency relations: The role of temporal contiguity. *Journal of the Experimental Analysis of Behavior*, **46**, 15-35.

WEARDEN, J. H., & CLARK, R. B. (1988). Interresponse time reinforcement and behavior under aperiodic reinforcement schedules: A case study using computer modelling. *Journal of Experimental Psychology: Animal Behavior Processes*, **14**, 200-211.

ZURIFF, G. E. (1970). A comparison of variable-ratio and variable-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, **13**, 269-374.

(Manuscript received February 24, 1992;
revision accepted for publication June 25, 1993.)