ACQUISITION OF LEVER-PRESS RESPONDING WITH DELAYED CONSEQUENCES IN RATS: IS A MINUTE TOO LONG?

ADQUISICIÓN DE LA RESPUESTA DE PALANQUEO EN RATAS CON CONSECUENCIAS DEMORADAS: ¿ES UN MINUTO DEMASIADO LARGO?

SUSAN SNYCERSKI, SEAN LARAWAY, TOM BYRNE, AND ALAN POLING[1]
WESTERN MICHIGAN UNIVERSITY

ABSTRACT

Sixteen water-deprived rats were exposed to 30 4-hr sessions in which responses on one lever produced water under a resetting delay of 60 s and responses on a second lever canceled any scheduled water deliveries. Previous studies have demonstrated response acquisition within one session under similar procedures with shorter (e.g., 30-s) delays, but there was no evidence of consistent response acquisition in the present study. Although 10 rats emitted several more responses on the lever that produced water than on the lever that canceled water deliveries on the first day, and received more than 10 water deliveries, this pattern only persisted for two rats. None of the rats that failed to acquire the response during the initial session acquired the response over subsequent sessions. These findings suggest that responding is not necessarily strengthened by protracted exposure to resetting delay arrangements and that patterns of responding observed on initial exposure to such arrangements may differ substantially from those observed subsequently.

Key words: acquisition, delayed consequences, delayed reinforcement, unsignaled delay, lever-press response, rats

---

RESUMEN

Dieciseis ratas privadas de agua fueron expuestas a 30 sesiones de 4 hrs en las que las respuestas a una palanca producían agua bajo una demora reciclante de 60 s y las respuestas en una segunda palanca cancelaban cualquier entrega de agua programada. Estudios previos habían demostrado la adquisición de la respuesta intrasesión con procedimientos similares con demoras más cortas (e.g., 30-s), sin embargo en este estudio no existió evidencia de la adquisición consistente de la respuesta. Aunque durante el primer día 10 ratas emitieron un mayor número de respuestas en la palanca que producía agua, que en la palanca que cancelaba la entrega del agua y recibieron más de 10 entregas de agua, este patrón sólo persistió para dos ratas. Las ratas que no adquirieron la respuesta durante la sesión inicial tampoco lo hicieron durante las siguientes sesiones. Estos resultados sugieren que el responder no necesariamente se fortalece por la exposición prolongada a la demora reciclante y que los patrones de respuesta observados durante la exposición inicial a dicha demora pueden diferir substancialmente de aquéllos observados después.

Palabras clave: adquisición, consecuencias demoradas, reforzamiento demorado, demora reciclante, palanqueo, ratas

---

The role of delay in mediating the behavioral effects of response-produced events has been explored in a number of studies. Procedural details influence obtained results, but there is overwhelming support for the view that, unless mediating events are arranged, the reinforcing (or punishing) effects of a particular event decline rapidly with delay (Schneider, 1990). Nonetheless, delayed events can serve as reinforcers. For example, Lattal and Gleeson (1990) demonstrated the acquisition of lever-press responding in rats and key-peck responding in pigeons when unsignaled food deliveries were delayed by up to 30 s relative to the response that produced them.

Lattal and Gleeson's findings are noteworthy in that rats learned to press levers and pigeons learned to peck keys under both nonresetting and resetting delay procedures when neither hand shaping nor autoshaping were arranged. Under the former procedure, which can be denoted a tandem fixed-ratio 1 fixed-time t (FR 1 FT t) schedule, the first response initiates a delay and responses during the delay have no programmed consequences. Thus, obtained delays can be shorter than programmed delays. Under the latter procedure, which can be construed as a tandem fixed-ratio 1 not-responding-for-greater-than-t (FR 1 $R > t$) schedule, programmed and obtained delays are equivalent.

A problem with resetting delays is that arranging a $R > t$ schedule reduces the rate of occurrence of established operants, and the magnitude of

the response reduction often increases with the duration of t (e.g., Zeiler, 1971, 1976, 1979). The value of t defines the delay to delivery of the scheduled consequence under resetting procedures and, at long delays, subjects are exposed to both delayed consequences and a powerful response-reducing schedule. Given this, it is perhaps not surprising that prior studies have shown that at resetting delays of 16 and 32 s rats emitted as many, or more, responses on a lever that produced no consequences as on a lever that produced the putative reinforcer (i.e., food or water) (LeSage, Byrne, & Poling, 1996; Wilkenfield, Nickel, Blakely, & Poling, 1992).

Sutphin, Byrne, and Poling (1998) proposed that responses on a no consequences lever may be reinforced adventitiously by events produced by responses on the reinforcement lever. The effects of this adventitious reinforcement, which is not delayed by a predetermined value and may be immediate, could spread by induction to the reinforcement lever. Sutphin et al. (1998) therefore examined a procedure under which responses on a reinforcement lever produced water after a resetting delay and responses on a cancellation lever terminated any scheduled water delivery. This procedure eliminated the possibility that responses on the cancellation lever could be adventitiously reinforced.

To determine whether the reinforcement/cancellation procedure would yield results different from those obtained with the reinforcement/no consequences procedure, Sutphin et al. also arranged delay procedures comparable to those used by LeSage et al. (1996). During a single 8-hr session under the resetting/cancellation procedure there was evidence of differential responding on the two levers at delays of 16 and 32 s, but there was no evidence of differential responding at these same delays under the resetting/no consequences arrangement. The former results provide unambiguous evidence that consequences delayed by up to 30 s can affect behavior.

To determine whether rats can learn to lever press with even longer delays under the resetting/cancellation procedure, rats were exposed to 60-s delays in the present study. Avila and Bruner (1995) previously demonstrated the acquisition of lever-pressing in rats with nonresetting delays of 60 s and longer, but obtained delays were considerably shorter than the nominal delays. To date, there is no compelling evidence of consistent response acquisition at delays greater than approximately 30 s under resetting procedures. However, in the Sutphin et al. (1998) study, four of the eight rats exposed to a 64-s delay appeared to have acquired the response. Although not compelling, and inconsistent with some theoreticians' claim that events delayed by a minute or more are not effective as reinforcers (Malott, Whaley, & Malott, 1997), these results suggest that rats may learn to lever press when the consequences of responding are delayed by about a minute. Sutphin et al. (1998) proposed that

longer exposure to the reinforcement/cancellation procedure would increase the probability of response acquisition at such delay values. The present study tested this proposition by exposing rats to a 60-s delay under the resetting/cancellation procedure for 30 4-hr sessions.

METHOD

Subjects

Sixteen experimentally-naïve male Sprague-Dawley rats, approximately 50 days of age, served as subjects. The rats were water deprived as described below and were housed in groups of four with unlimited access to food in a colony area with a 12-hr light/dark cycle.

Apparatus

Eight MED Associates (St. Albans, VT) operant test chambers were used. The chambers were 28 cm long by 21 cm wide by 21 cm high. During response-acquisition sessions, two response levers separated by 8.5 cm were mounted on the front panel 7 cm above the chamber floor. A minimum force of 0.14 N was required to operate the levers. A receptacle located in the center of the front panel 3 cm above the chamber floor allowed access to a dipper filled with 0.1 ml of tap water. Chambers were illuminated by a 7-W white bulb located on the ceiling. An exhaust fan in each chamber masked extraneous noise and provided ventilation. Programming of experimental events and data recording were controlled by a microcomputer equipped with MED-PC software.

Procedure

All rats were water deprived for 24 hr prior to one 60-min dipper training session. During dipper-training sessions response levers were removed and water was delivered under a variable-time 60-s schedule. Under this schedule, 4-s dipper presentations occurred randomly on average once every 60 s, regardless of the rat's behavior. All rats were observed to drink from the dipper by the end of the session. At the end of dipper-training sessions rats were returned to their home cages. At that time, they were randomly assigned to one of two groups of eight.

Rats in Group 1 were exposed to the response-acquisition procedure every Monday, Wednesday, and Friday, whereas rats in Group 2 were exposed

to the procedure every Tuesday, Thursday, and Sunday. Testing continued until 30 response-acquisition sessions had been arranged for each rat. For all rats, unlimited access to water was provided for 24 hr after each experimental session, and removed 24 hr later. Therefore, all rats were deprived of water for 24 hr prior to behavioral testing.

Response-acquisition sessions began at approximately 8:00 p.m. and lasted for 4 hr. During these sessions, the rats were exposed to a tandem FR 1 R > 60-s schedule on the reinforcement lever. Here, the first response initiated a delay of 60 s, after which water was delivered for 4 s. Responses on the reinforcement lever during the delay reset the interval. The left lever was designated as the reinforcement lever for the rats in Group 1, and the right lever was designated as the reinforcement lever for those in Group 2. If a response occurred on the other (cancellation) lever during a delay interval, the current delay interval was terminated and the scheduled water delivery did not occur. In such cases, a response on the reinforcement lever was required to restart the delay. All responses on both levers were recorded, as were all water deliveries.

RESULTS

Table 1 shows the total number of responses emitted by individual rats on the reinforcement and cancellation levers and the total number of water deliveries during the first and last experimental sessions (i.e., Sessions 1 and 30). During the first experimental session, 10 of the 16 rats (1, 2, 3, 6, 7, 8, 9, 12, 13, and 14) responded more on the reinforcement lever than on the cancellation lever and earned at least 10 water deliveries. These data provide some evidence that these rats were sensitive to programmed consequences, and acquired the operant response. However, during the final session, only two of these rats (2, 8) emitted more responses on the reinforcement lever than on the cancellation lever and earned at least 10 water deliveries.

No rat that failed to acquire responding during the first session subsequently acquired the reinforcement-lever response as a function of repeated exposure to the resetting delay procedure. In fact, for nearly all individual rats and for the rats as a group (Figure 1), the total number of reinforcement-lever responses emitted on session 1 was significantly less ($t = 6.62$, $p < .01$) than the number emitted in Session 30. As a group, the rats made significantly fewer responses on the cancellation lever ($t = 6.33$, $p < .01$) and earned significantly fewer water deliveries ($t = 4.98$, $p < .05$) during Session 30 than during Session 1 (Figure 1). Figure 2 shows that, for the rats a group, the mean number of reinforcement-lever responses declined rather rapidly across the first 3 sessions and more slowly and less consistently across

subsequent sessions. Similar, but less pronounced, patterns were evident in the group mean data for cancellation-lever responses and water deliveries (Figure 2).

Table 1. Total Number of Responses Emitted by Individual Rats on the Reinforcement and Cancellation Levers, and the Total Number of Water Deliveries, for the First and Last Experimental Sessions (Sessions 1 and 30)

	Session 1			Session 30		
Rat	Reinforcement-Lever Responses	Cancellation-Lever Responses	Water Deliveries	Reinforcement-Lever Responses	Cancellation-Lever Responses	Water Deliveries
1	128	12	38	5	7	3
2	77	25	18	16	3	12
3	77	25	18	1	5	1
4	26	52	5	4	4	3
5	26	56	9	4	0	3
6	123	98	16	23	27	10
7	67	33	23	0	2	0
8	15	1	11	15	4	12
9	30	16	10	0	4	0
10	60	65	17	6	8	4
11	55	74	7	2	3	2
12	59	18	22	0	0	0
13	81	55	24	0	0	0
14	62	27	23	4	0	3
15	19	52	5	1	4	1
16	38	54	11	6	8	4

Although the rats as a group emitted substantially more responses on the reinforcement lever than on the cancellation lever during the first session, this difference was not statistically significant ($t = 1.79, p > .05$). During Session 30, the rats responded at approximately equivalent levels on the two levers.

DISCUSSION

Several studies previously have demonstrated consistent response acquisition with reinforcer delivery delayed by up to approximately 30 s (Byrne, LeSage, & Poling, 1997; Critchfield & Lattal, 1993; Dickinson, Watt, & Griffiths, 1992; Lattal & Gleeson, 1990; LeSage et al., 1996; Schlinger & Blakely, 1994; van Haaren, 1992; Wilkenfield et al., 1992). Response acquisition also has been demonstrated with nonresetting and aperiodic delays of 60 s and longer (Avila & Bruner, 1995). This latter procedure, however,

allowed average obtained delays to be shorter than the nominal values and also for brief delays to occur.
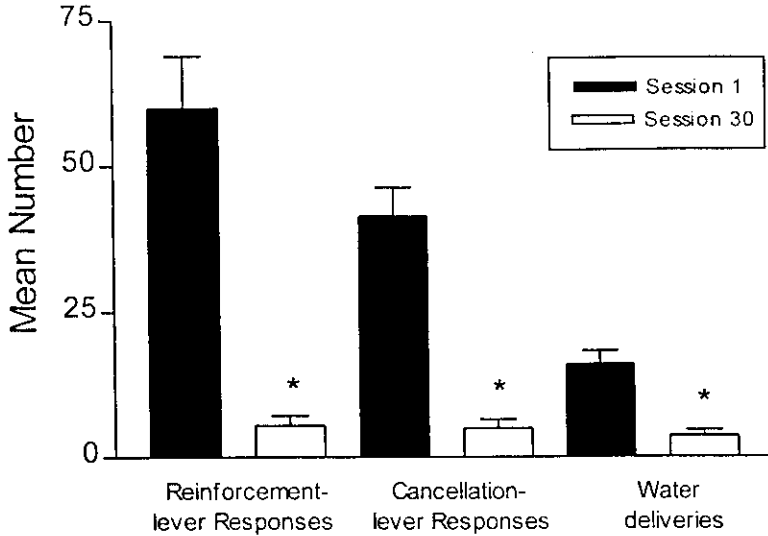

Figure 1. Mean number (+ 1 S.E.M.) of total responses on the reinforcement and cancellation levers, and mean number of total water deliveries for the rats as a group for session 1 and session 30. Asterisks indicate significant (*p* < .01) differences in performance during the two sessions.
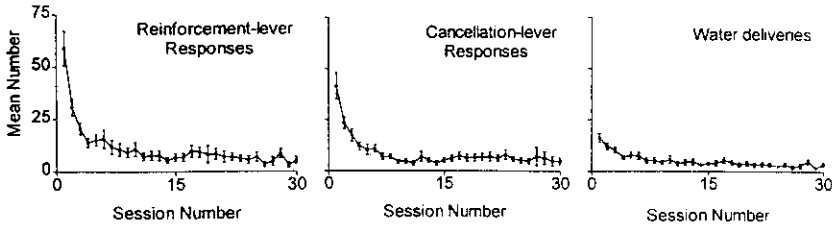

Figure 2. Mean number (±1 S.E.M.) of total reinforcement and cancellation lever responses, and mean number of total water deliveries, for the rats as a group, for all experimental sessions (i.e., sessions 1-30).

Sutphin et al. (1998) reported that four of eight rats exposed to procedures comparable to those used in the present study provided some evidence of response acquisition at delays of 64 s in a single 8-hr session. They proposed that exposing rats to similar delays under such procedures for longer periods might engender robust responding by most rats. The present

results provide no evidence to support this proposition. Although there is no consensus as to the criteria that should be used to determine when a new operant response has been acquired (for discussion of this point, see Sutphin et al., 1998; Wilkenfield et al., 1992), 10 of 16 rats in the present study responded substantially more on the reinforcement lever than on the cancellation lever, and obtained at least 10 water deliveries, during the first 4-hr session. These data could be construed as providing evidence, albeit relatively weak evidence, of response acquisition.

If those 10 rats had learned to press the reinforcement lever, this response was not maintained across sessions by most (eight) of them. In these rats, the number of responses on the reinforcement lever decreased markedly across sessions, as did the number of water deliveries. In addition, the differential responding on the two levers that was evident in the first session generally disappeared with further exposure to the reinforcement/cancellation procedure. Moreover, none of the rats that failed to acquire the reinforcement-lever response during the initial session did so over subsequent sessions. These findings indicate that reinforcement-lever responses were not strengthened by protracted exposure to resetting delay arrangements and that patterns of responding observed on initial exposure to such arrangements differed substantially from patterns observed after repeated exposure.

Williams (1983) suggested that "separate laws of behavior are involved" (p. 77) in the acquisition and maintenance of responding, and the present data are consistent with this view. It is not, however, obvious why the rats that emitted a substantial number of responses on the reinforcement lever during the first session failed to maintain this level of performance. In one prior study involving rats exposed to shorter resetting delays, substantial responding was evident across 10 sessions (Lattal & Gleeson, 1990, Experiment 5). In another study, responding occurred across 20 or more sessions (Critchfield & Lattal, 1993). These findings make it clear that events delivered under resetting delays may engender responding that persists over time. It is possible that some of the rats in the present study were affected by the positive response-water dependency arranged in the first session, and this dependency engendered responding on the reinforcement lever. Over time, however, the response-weakening effects of the negative response-water dependency arranged on both levers competed effectively with the response-strengthening effects of the positive dependency, and responding fell to low levels. Put differently, across time the response-strengthening effects of reinforcement delayed by 1 min were insufficient to overcome the response-weakening effects of the $R > 1$-min arrangement in the present study. In contrast, with shorter delays (e.g., 30 s) arranged under similar procedures in prior studies (Lattal & Gleeson, 1990; Critchfield & Lattal, 1993), the response-strengthening effects

of delayed reinforcement were greater than the response-weakening effects of the resetting delay. If this analysis is correct, it illustrates that the procedures used to program delayed events can affect behavior in multiple ways, which complicates analysis of the effects of delay per se (cf. Lattal, 1987).

As others have emphasized (e.g., Lattal, 1987; Schneider, 1990; Wilkenfield et al., 1992), the sensitivity of behavior to delayed reinforcement is affected by a variety of procedural details (see Lattal, 1987) and the present data in no way prove that rats cannot acquire lever-press responding under resetting delays of reinforcement equal to or greater than one minute. It is naïve to believe that there is a finite value at which reinforcement becomes ineffective for a given species. But it may nonetheless be worthwhile to determine the maximal delay value at which responding can be consistently acquired under procedures similar to those used in the present study. Evans and Wenger (1992) suggest that behavioral pharmacologists have largely ignored drug effects on the initial acquisition of operant behavior, and the resetting/cancellation procedure may be useful for this purpose (see Snycerski, Laraway, Byrne, & Poling, 1998). Snycerski et al. suggest that procedures involving delayed reinforcement may be especially sensitive to drug effects, and it might be the case that the greatest sensitivity will be revealed at the longest delay that consistently generates responding in the absence of drug. Results of the present study and those of earlier investigations suggest that this value is longer than 30 s, but shorter than 1 min.

REFERENCES

Avila, S. R., & Bruner, C. A. (1995). Response acquisition under long delays of signaled and unsignaled reinforcement. *Mexican Journal of Behavior Analysis, 21*, 117-127.

Byrne, T., LeSage, M.G., & Poling, A. (1997). Effects of chlorpromazine on rats' acquisition of lever-press responding with immediate and delayed reinforcement. *Pharmacology Biochemistry and Behavior, 58*, 31-35.

Critchfield, T. S., & Lattal, K. A. (1993). Acquisition of a spatially defined operant with delayed reinforcement. *Journal of the Experimental Analysis of Behavior, 59*, 373-387.

Dickinson, A., Watt, A., & Griffiths, W. J. H. (1992). Free-operant acquisition with delayed reinforcement. *The Quarterly Journal of Experimental Psychology, 45B*, 241-258.

Evans, E. G., & Wenger, G. R. (1992). Effects of drugs of abuse on acquisition of behavioral chains in squirrel monkeys. *Psychopharmacology, 107*, 55-60.

Lattal, K. A. (1987). Considerations in the experimental analysis of reinforcement delay. In M. L. Commons, J. E. Mazur, J. A. Nevin, and H. Rachlin (Eds.), *Quantitative*

analysis of behavior: Vol. 5:   The effect of delay and intervening events on
     reinforcement value (pp. 107-123). Hillsdale, NJ: Erlbaum.
Lattal, K. A., & Gleeson, S. (1990). Response acquisition with delayed reinforcement.
     Journal of Experimental Psychology: Animal Behavior Processes, 16, 27-39.
LeSage, M. G., Byrne, T., & Poling, A. (1996). Effects of *d*-amphetamine on response
     acquisition with immediate and delayed reinforcement. *Journal of the
     Experimental Analysis of Behavior, 66,* 349-367.
Malott, R. W., Whaley, D. L., & Malott, M. E. (1997). *Elementary principles of behavior.*
     (3rd Ed.). Upper Saddle River, NJ: Prentice-Hall.
Schlinger, H. D., Jr., & Blakely, E. (1994). The effects of delayed reinforcement and a
     response-produced auditory stimulus on the acquisition of operant behavior in
     rats. *Psychological Record, 44,* 391-409.
Schneider, S. M. (1990). The role of contiguity in free-operant unsignaled delay of
     positive reinforcement: A brief review. *The Psychological Record, 40,* 239-257.
Snycerski, S., Laraway, S., Byrne, T., & Poling, A. (1998). Drug effects on response
     acquisition with immediate and delayed reinforcement. *Research Trends, 4,*
     143-152.
Sutphin, G., Byrne, T., & Poling, A. (1998). Response acquisition with delayed
     reinforcement: A comparison of two-lever procedures. *Journal of the
     Experimental Analysis of Behavior, 69,* 17-28.
van Haaren, F. (1992). Response acquisition with fixed and variable resetting delays of
     reinforcement in male and female Wistar rats. *Physiology and Behavior, 552,*
     769-772.
Wilkenfield, J., Nickel, M., Blakely, E., & Poling, A. (1992). Acquisition of lever-press
     responding in rats with delayed reinforcement: A comparison of three
     procedures. *Journal of the Experimental Analysis of Behavior, 58,* 431-443.
Williams, B. A. (1983). Revising the principle of reinforcement. *Behaviorism, 11,* 63-88.
Zeiler, M. D. (1971). Eliminating behavior with reinforcement. *Journal of the
     Experimental Analysis of Behavior, 16,* 401-405.
Zeiler, M. D. (1976). Positive reinforcement and the elimination of reinforced behavior.
     Journal of the Experimental Analysis of Behavior, 26, 37-44.
Zeiler, M. D. (1979). Reinforcing the absence of fixed-ratio performance. *Journal of the
     Experimental Analysis of Behavior, 31,* 321-332.