

Positive Reinforcement as a Correlation Between Lever Pressing and Increase in Frequency of food Pellet Delivery in rats¹

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ABSTRACT

Lever pressing in food-deprived rats was acquired when it increased the probability of food pellet delivery even when a pellet could not follow a response by less than 10 seconds. The probability of acquisition was decreased by increasing the frequency of pellet delivery in the absence of responding. Response rates were higher when some responses were immediately followed by a pellet but were low when pellets were delivered independently of responding. The results support the notion that a correlation between responding and positive reinforcer delivery, in the sense that responding increases the frequency of reinforcer delivery, is sufficient to produce response acquisition in the absence of response-reinforcer contiguity.

RESUMEN

Ratas privadas de comida adquirieron la conducta de apretar la palanca cuando ésta aumentó la probabilidad de entrega de píldoras de comida aun cuando un píldora no podía seguir una respuesta antes de 10 segundos. La probabilidad de adquisición disminuyó al aumentar la frecuencia de entrega de píldora en ausencia de respuesta. Las tasas de respuesta fueron mayores cuando algunas respuestas se vieron seguidas por una píldora pero fueron bajas cuando las píldoras se entregaron independientemente de la respuesta. Los resultados apoyan la noción de que una correlación entre la respuesta y la entrega del reforzador positivo, en el sentido de que la respuesta aumenta la frecuencia de administración del reforzador, es suficiente para producir la adquisición de respuesta en ausencia de la contigüidad respuesta-reforzador.

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Research has indicated that responses can be acquired and maintained when responding changes the frequency of certain events occurring randomly in time. Herrnstein and Hineline (1966) showed that rats will acquire a lever-press response when responding decreases the probability of shock presentation from, for example, 0.3 in a 2 sec period to 0.1 in a 2 sec period. In Herrnstein and Hineline's experiment, lever pressing was acquired and maintained in 17 of 18 subjects although no external stimulus accompanied either of the schedules and a shock sometimes occurred immediately after a lever press.

Coulson, Koffer, and Coulson (1971), using what was basically a positive reinforcement analogue of Herrnstein and Hineline's procedure, presented two bottles containing water or a 9% (volume/volume) solution of ethyl alcohol simultaneously to food-deprived rats. Licking one of the bottles changed the average density of randomly delivered food pellets from 0.5 per min to 4 per min. Although a pellet could not follow the reinforced response by less than 3 sec, this schedule increased the consumption of the liquid whose drinking produced the higher pellet density.

Smith and Clark (1972), using food-deprived rats, examined maintenance of lever pressing on a schedule in which lever pressing changed the frequency of food pellet delivery. There were two sources of pellets in Smith and Clark's experiment. Responding was reinforced on a tandem (*tand*) schedule in which responding on a fixed-ratio 1 (FR 1) schedule started a differential reinforcement for other behavior (DRO) interval during which a response restarted the interval. A pellet was delivered at the end of the DRO period. Smith and Clark varied the duration of the DRO interval from 0 to 90 sec. In the absence of lever pressing, pellets were delivered periodically with interpellet times ranging from 5 to 600 sec in different phases of the experiment. In general, responding was maintained when it produced a higher frequency of pellet delivery than not responding.

It is important to note that most experiments using a DRO component preceding reinforcer delivery (e.g., Dews, 1960; Smith and Clark, 1972) have typically provided their subjects with considerable initial exposure to schedules with immediate positive reinforcement examining the effect of a DRO interval on maintained responding. The main purpose of the present experiments was to determine if, and under what circumstances, acquisition of lever pressing would occur when naïve subjects were exposed to a contingency in which responding increased the density of randomly delivered reinforcers. The main constraint on randomness of reinforcer delivery was a minimum delay between a response and pellet delivery designed to eliminate the possibility of immediate, adventitious reinforcement.

Experiment 1

Experiment 1 investigated some of the variables affecting acquisition when responding increased the temporal density of reinforcer delivery.

The first group of subjects was used to determine whether lever pressing would be acquired if it increased pellet density from an average of one per 120 sec to an average of one per 15 sec when the minimum interval between a response and pellet delivery was 3 sec. Two further groups of subjects were used to indicate if acquisition would occur if the minimum response-pellet time was increased to 5 or 10 sec.

Smith and Clark (1972) have shown that as the frequency of pellet delivery in the absence of responding increased, the frequency of an established response decreased. A fourth group of subjects was used to determine the effect on acquisition of increasing the frequency of pellet delivery in the absence of responding.

Method

Subjects

A total of 16, 90 day old, male albino Wistar rats served. Food deprivation began seven days before the first experimental session and maintained each subject at 80% of its free-feeding weight, with corrections for normal growth, throughout the experiment. The subjects were individually housed with free access to water except during experimental sessions.

Apparatus

The experimental chamber used for subjects 6 to 9 and 125 to 128 was 29.5 by 27 by 25 cm with a grid floor. The chamber used for subjects 131 to 138 was 23.3 by 19.7 by 18.5 cm with a grid floor. A Lehigh Valley rat lever (Model 1352) was mounted on an end wall of each chamber with its center 10 cm from the door and its top 7.2 cm from the floor. The lever projected 3 cm into the chamber and required a downward force of 14 gm (0.14 N) through an excursion of 2 mm to operate. Standard formula, 45-mg Noyes pellets were delivered to a food cup mounted beside the lever and each pellet was accompanied by a 0.3-sec buzz. Illumination was provided by a 7-W houselight. Each chamber was housed inside a sound-attenuating shell with a fan providing ventilation and masking noise. Electromechanical control and recording equipment was housed in an adjacent room and subjects were monitored on a closed-circuit television system.

Procedure

The first two sessions for all subjects consisted of magazine training with the lever absent. During the first session, which lasted 1 hr, pellets were delivered independently of the subject's behavior at variable inter-pellet times averaging 30 sec. This defined a variable-time 30-sec (VT 30-sec)

schedule. During the second session, which lasted 2 hr, pellets were delivered on a VT 120-sec schedule. The lever was returned on the third session and the experiment began. Lever pressing was not shaped in any way but subjects were simply exposed to the schedules as outlined below. After magazine training, each session lasted for 2 hr or until 200 pellets were delivered, whichever came first. Sessions were run on successive days and, unless otherwise specified, two interdependent schedules delivered pellets. In the absence of lever pressing, pellets were delivered by a tape programmer on a VT schedule. A lever press switched control of pellet delivery to another schedule. When a pellet was delivered from the second schedule, control of pellet delivery switched to the first schedule.

The details of the two schedules were as follows: A lever press started a tape programmer which ran for an average of x sec. A response made during the x sec had no programmed effect. At the end of the x sec, a fixed duration timer started and ran for y sec, provided a response did not occur. A response made while the y -sec timer was running restarted the y -sec interval. When the y -sec timer timed out, a pellet was delivered. The response-schedule (R-schedule) was, therefore, a tandem (*tand*) schedule consisting of a fixed-ratio 1 (FR 1) component, a variable-time component an average of x sec long (VT x -sec), and a differential reinforcement for other behaviour component y sec long (DRO y -sec). Altogether the R-schedule was a *tand* FR 1 VT x -sec DRO y -sec schedule. In the present experiments, the sum of x and y was always 15 sec.

The no-response (\bar{R} -schedule) delivered pellets on a VT schedule programmed by a second tape timer which ran at all times except when the R-schedule was in effect and for 1.5 sec after pellet delivery. The purpose of the 1.5-sec post-pellet interval was to allow the subject to go to the food cup, obtain the pellet, and get ready to respond again. The \bar{R} -schedule was in effect at the beginning of each session and remained in effect until a response occurred. Values for the VT tapes used in the R-schedule, the \bar{R} -schedule, and in magazine training were taken from Fleshler and Hoffman's (1962) progression for generating variable interval schedule values. Each schedule had two different tapes which were alternated from session to session.

After magazine training, subjects 6 to 9 were exposed to a VT 120-sec R-schedule and a *tand* FR 1 VT 12-sec DRO 3-sec \bar{R} -schedule for at least 18 sessions. Subjects 135 to 138 were exposed to a VT 120-sec \bar{R} -schedule and a *tand* FR 1 VT 10-sec DRO 5-sec R-schedule in which a pellet could not follow a lever press by less than 5 sec. Subjects 131 to 134 were run on a VT 120-sec R-schedule and a *tand* FR 1 VT 5-sec DRO 10-sec \bar{R} -schedule in which a pellet could not follow a lever press by less than 10 sec. Subjects 131 to 138, with the exception of 132, were run for 10 sessions following magazine training. Because subject 132 did not press the lever more than twice in any of his first five sessions, his weight was reduced to 70% of his free-feeding weight during two days and he received 10 additional sessions.

Subjects 125 to 128 were placed on a VT 45-sec \bar{R} -schedule and a *tand* FR 1 VT 12-sec DRO 3-sec R-schedule. The VT 45-sec \bar{R} -schedule remained in effect until an acquisition criterion of two or more responses per min for five consecutive sessions was met. If the response rate was less than 0.5 per min for six consecutive sessions, the \bar{R} -schedule was changed to VT 90-sec until the acquisition criterion was met.

Results

Figure 1 indicates that substantial response rates were produced for subjects 6 to 9 when responding increased the frequency of pellet delivery from an average of one per 120 sec to one per 15 sec.

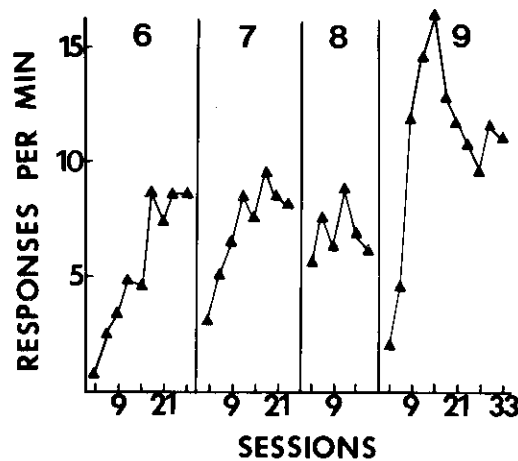


Figure 1. Response per min averaged over three sessions for subjects 6 to 9. Each subject was on a *tand* FR 1 VT 12-sec DRO 3-sec R-schedule and a VT 120-sec R-schedule.

As shown in Figure 2, responding was produced by both R-schedules with no clear indication that rates were higher under the DRO 5-sec value than under the DRO 10-sec value. Subjects with a DRO 10-sec requirement did, however, take longer to obtain 200 pellets than did subjects with a DRO 5-sec requirement. The subjects with a DRO 10-sec requirement took an average of 101 min, with a range of 91 to 114 min, to obtain 200 pellets during their last 5 sessions compared with an average of 84 min, with a range of 82 to 88 min for the subjects with a DRO 5-sec requirement. The difference in session duration was partially due to the greater delay of pellet delivery produced by responding during the DRO 10-sec component.

An increase in deprivation level may have increased subject 132's rate by increasing his activity level and/or by making the increase in pellet

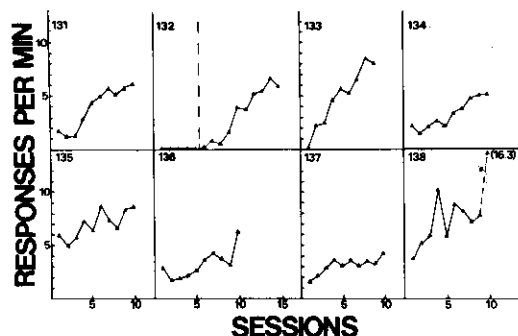


Figure 2. Response per min for subjects 131 to 138 as a function of session number. Subjects 131 to 134 were run on a *tand* FR 1 VT 5-sec DRO 10-sec R-schedule and subjects 135 to 138 on a *tand* FR 1 VT 10-sec DRO 5-sec R-schedule. The R-schedule was VT 120-sec for all subjects. Subject 132's weight was 80% of his free-feeding weight before the broken line and 70% in the 10 sessions after. All other subjects were run at 80% of their free-feeding weights.

density produced by responding more reinforcing. A two day rest, by itself, has not increased response rates in rats run in our laboratory under similar circumstances.

As shown in Figure 3, subjects 127 and 128 met the acquisition criterion on a VT 45-sec R-schedule while subjects 125 and 126 did not meet the criterion until the pellet density of the R-schedule was decreased to an average of one pellet every 90 sec.

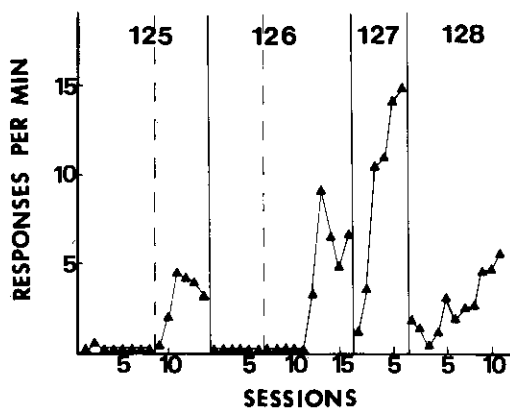


Figure 3. Response per min for subjects 125 to 128 as a function of session number. All subjects were run on a *tand* FR 1 VT 12-sec DRO 3-sec R-schedule and all subjects started with VT 45-sec R-schedule which was changed to VT 90-sec for subjects 125 and 126 during the sessions following the broken line.

Closed-circuit television observation revealed no systematic behavior chains mediating between responding and pellet delivery for any of the subjects in Experiment I.

Discussion

The present experiment demonstrates that substantial response rates can be generated in naïve rats when responding increases the frequency of pellet delivery from a non-zero level, even when a pellet cannot follow a response by less than 10 sec.

The results also support Smith and Clark's (1972, p. 9) suggestion that preliminary training with immediate reinforcement is not necessary for responding to be maintained on schedules in which a response-initiated DRO component terminates with pellet delivery.

The results from subjects 125 to 128 extend Smith and Clark's (1972) results on maintained responding by showing that an increase in the frequency of pellet delivery in the absence of responding can reduce the probability of acquisition.

Experiment 2

Experiment 2 was designed to compare the response rates produced by the kinds of schedules used in Experiment 1 with two more common schedules.

One group of subjects was used to assess the effect of contiguity between responding and pellet delivery under two schedules with equal potential pellet density. In one schedule, a response-produced pellet was delivered immediately after a response, while in the other, a minimum 3-sec delay occurred between a response and pellet delivery.

Rescorla and Skucy (1969) have shown that some lever pressing will occur when pellets are delivered to naïve rats independently of lever pressing. A second group of subjects was used to compare the response rates produced by response-independent pellet delivery with those produced by the kind of schedules used in Experiment 1 to determine what proportion of lever pressing was produced by pellet delivery *per se*.

Method

Subjects

Eight experimentally naïve subjects, with the same characteristics as those used in Experiment 1, were used in the present experiment. Deprivation conditions were identical to those of Experiment 1.

Apparatus

The experimental chamber used for subjects 6 to 9 was used for subjects A to D. In addition, an identical chamber was also used with subjects E to H.

Procedure

After magazine training, subjects A and B were placed on a *tand* FR 1 VT 12-sec DRO 3-sec R-schedule and a VT 120-sec \bar{R} -schedule. Subjects C and D were placed on a standard variable-interval 15-sec (VI 15-sec) \bar{R} -schedule coupled with a VT 120-sec \bar{R} -schedule. During sessions with the VI 15-sec R-schedule, the \bar{R} -schedule tape programmer ran only when a pellet was available from the VI 15-sec schedule. The \bar{R} -schedule tape programmer stopped for 1.5 sec following delivery of a \bar{R} -schedule pellet. In the second phase of the experiment, subjects A and B were switched to the VI schedule and C and D to the *tand* schedule. Each phase lasted at least 15 sessions for an individual subject.

Following magazine training, subjects E and H were placed on a *tand* FR 1 VT 12-sec DRO 3-sec R-schedule and a VT 120-sec \bar{R} -schedule. In the first phase of the experiment, all the pellets received by subjects F and G were response-independent. Subject F received pellets at the same time as E and subject G at the same time as H. These conditions were reversed in the second phase with response-independent pellets being delivered to subjects E and H. The first and second phases lasted 9 and 18 sessions, respectively, for the E-F pair and 8 and 25 sessions, respectively, for the G-H pair.

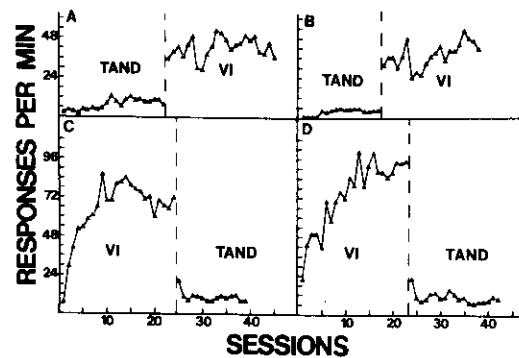


Figure 4. Response per min for subjects A to D as a function of type of R-schedule. Subjects A and B started with a *tand* FR 1 VT 12-sec DRO 3-sec R-schedule and then switched to a VI 15-sec R-schedule. The reverse conditions obtained for subjects C and D. The R-schedule was VT 120-sec for all sessions.

Results

As shown in Figure 4, response rates for subjects A to D were much higher under the VI schedule than under the *tand* schedule. Also of note is the immediacy with which response rates changed with a change in schedule.

As shown in Figure 5, response rates were higher in the first phase for the subjects on the response-dependent schedule and, when conditions were reversed in the second phase, response rates for the subjects on the response-independent schedule eventually declined below those of the response-dependent subjects.

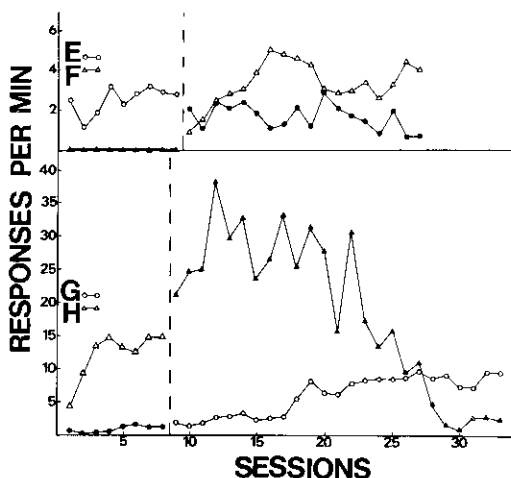


Figure 5. Response per min for pairs E-F and G-H as a function of session number and response-dependent or response-independent pellet delivery. Open symbols indicate sessions in which pellets were response-dependent and closed symbols indicate sessions in which pellets were response-independent with the broken line representing the phase change. When pellets were response-dependent, subjects were on a *tand* FR 1 VT 12-sec DRO 3-sec R-schedule and a VT 120-sec R-schedule. The ordinate scale of the E-F pair is expanded to show detail of their response rates.

Discussion

A possible explanation for the lower response rates produced by the *tand* schedule for subjects A to D is that the DRO requirement punished responses occurring within 3 sec of pellet delivery by postponing pellet delivery. That this explanation might not obtain is suggested by an experiment (Coulson, 1970; Experiment D) in which responding on a VI 15-sec R-schedule occurred at a much higher rate than responding on a *tand* FR 1 VT 15-sec R-schedule. The latter *tand* schedule does not require a

no-response period before pellet delivery and consequently, responding could not be punished by pellet postponement. This suggests that the lack of contiguity between response and pellet delivery in the *tand* schedule used with subjects A to D was of primary importance in their lower response rates.

The results of subjects E to H indicate that pellet delivery *per se* produced very little responding in naïve rats with the apparatus and procedures used in the present experiments.

Observation of subject H disclosed that the elevation in his response rate when he was switched to response-independent pellet delivery seemed to be due to the occasional instances of close response-pellet contiguity which occurred during his first sessions on the response-independent procedure.

General discussion

The present results indicate that neither immediate reinforcement of at least some responses nor a special kind of R-schedule which delivers no reinforcers: two factors present in most positive reinforcement schedules, are necessary to produce response acquisition.

Results similar to the present ones have led Herrnstein (1969), Schoenfeld and Farmer (1970), and Baum (1973) to suggest that the "Law of Effect" should be based on "correlation" between responses and reinforcers rather than on "contiguity" between at least some responses and some reinforcers. Schoenfeld and Farmer (1970, p. 221) indicate that such a correlation would require that: "the distribution in time of R [responses] determines the distribution in time of reinforcements. . ."

There is some indication in the present results of the important variables in such a correlation. The present experiments show that some level of correlation greater than zero is required for acquisition and that a "higher" correlation, in the sense of a greater change in pellet density produced by responding, results in a higher probability of acquisition.

An alternative to the correlation explanation in accounting for the present results is that the average delay of reinforcement was longer for non-lever pressing responses than for lever pressing and so lever pressing increased in frequency. Perhaps, as Bloomfield (1972) has indicated, any explanation using a delay of reinforcement notion cannot be refuted since any schedule involving a correlation also involves some delay between responding and reinforcer delivery, leaving delay of reinforcement as a possible explanatory mechanism in all instances. In any case, subjects 131 to 134 in Experiment 1 did acquire lever pressing when the minimum delay between lever pressing and pellet delivery was 10 sec without exhibiting systematic collateral behaviour during the delay period.

In the two by two matrix that can be constructed by making contiguity-no contiguity one of the dimensions and correlation-no

correlation the other, all the cells can be filled with procedures using positive reinforcer delivery that result in acquisition in the free-operant situation.

An "ordinary" schedule, e.g., a VI schedule, contains both contiguity and correlation. In a schedule where contiguity occurs in the absence of correlation, response-independent reinforcer delivery may produce "superstitious" responding (Skinner, 1948), although the response may not be specifiable in advance. The present experiments show that acquisition can occur with correlation in the absence of contiguity, although correlation *with* contiguity produced much higher response rates in Experiment 2. "Acquisition" of key pecking by the pigeon occurs in some circumstances in the absence of both contiguity and correlation although this may represent a species-specific behavior, as Herrnstein and Loveland (1972) have pointed out.

REFERENCES

- Baum, W. M. The correlation-based Law of Effect. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 137-153.
- Bloomfield, T. M. Reinforcement schedules: Contingency or contiguity? In R. M. Gilbert and J. R. Millenson (Eds.), *Reinforcement: Behavioral analyses*. New York: Academic Press, 1972, pp. 165-208.
- Coulson, G. E. *Positive reinforcement as an increase in positive reinforcer density*. Unpublished doctoral dissertation, York University, 1970.
- Coulson, G. E., Koffer, K. B. and Coulson, V. Reinforcement of ethanol consumption in rats by an increase in the frequency of food-pellet delivery. *Psychonomic Science*, 1971, 23, 103-104.
- Dews, P. B. Free-operant behavior under conditions of delayed reinforcement. I. CRF-type schedules. *Journal of the Experimental Analysis of Behavior*, 1960, 3, 221-234.
- Fleshler, M. and Hoffman, H. S. A progression for generating variable-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 529-530.
- Herrnstein, R. J. Method and theory in the study of avoidance. *Psychological Review*, 1969, 76, 49-69.
- Herrnstein, R. J. and Hineline, P. N. Negative reinforcement as shock-frequency reduction. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 421-430.
- Herrnstein, R. J. and Loveland, D. H. Food-avoidance in hungry pigeons, and other perplexities. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 369-383.
- Rescorla, R. A. and Skucy, J. C. Effect of response-independent reinforcers during extinction. *Journal of Comparative and Physiological Psychology*, 1969, 67, 381-389.
- Schoenfeld, W. N. and Farmer, J. Reinforcement schedules and the "behavior stream", In W. N. Schoenfeld (Ed.) *The Theory of Reinforcement Schedules*. New York: Appleton-Century-Crofts, 1970, pp. 215-245.
- Skinner, B. F. "Superstition" in the pigeon. *Journal of Experimental Psychology*, 1948, 38, 168-172.
- Smith, J. B. and Clark, F. C. Two temporal parameters of food postponement. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 1-12.