JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR VOLUME 9, NUMBER 1 JANUARY, 1966

THE MOTIVATIONAL PROPERTIES OF SCHEDULE-INDUCED POLYDIPSIA[1]

JOHN L. FALK

UNIVERSITY OF MICHIGAN

Schedule-induced polydipsia occurred during initial magazine training to Noyes pellets (45 mg), disappeared when lever-pressing was acquired on a continuous reinforcement schedule (CRF), and reappeared when the food contingency was changed to a 1-min variable interval schedule (VI 1 min). Polydipsia also developed under a VI 1 min food schedule when water was concurrently available on various fixed ratios (FR), rather than being freely available. The level of the polydipsia and its motivating properties allow it to be classified as a form of adjunctive behavior.

When water is freely available concurrently with daily VI 1 min sessions for 45 mg Noyes pellets[2], a pattern of excessive post-pellet drinking develops (Falk, 1961a). This polydipsia amounts to three or four times the normal 24-hr water intake within a 3.5-hr VI 1 min session. It does not occur on CRF, but any food schedule which lengthens inter-reinforcement time beyond approximately 30 sec seems to produce the effect (Falk, 1961b; Falk, 1966b). It is not acquired or maintained by adventitious reinforcement (Falk, 1961b; Falk, 1964; Stein, 1964). Further, the effect has been shown to develop under a free VI 1 min schedule wherein untrained animals were food deprived to 80% of free-feeding weight and the operation of the pellet dispenser was not contingent on a barpress (Falk, 1961b). These facts may be viewed as follows: drinking becomes highly probable with meal termination, but the amount drunk is under poor control of the amount eaten where meal size is severely limited. With an inter-pellet time greater than about 30 sec, each pellet constitutes a meal, and there are a large number of these small meals. Under CRF, inter-reinforcement time is short and meal size, or number of pellets consumed in close contiguity, would presumably approximate a natural meal size.

To determine the motivational properties of schedule-induced polydipsia two experiments were undertaken. In the first, differences among drinking patterns under magazine training, CRF and VI 1 min were studied. In the second, concurrent with the VI 1 min pellet schedule, water was not freely available but could be obtained from a water magazine on various FR schedules.

EXPERIMENT 1

Subjects

Three Irish, female rats were used. Two were littermates, designated I-61 and I-62, 3.5 months old at the start of the experiment, and both weighed 180 g. The third animal, I-70, was three months old and weighed 194 g. The Irish animals were a first generation cross between two inbred strains, brother-sister mated: an albino line and a black, non-agouti, selfed line. They were individually housed in a temperature-controlled, constantly-illuminated room.

Procedure

The experimental space consisted of a picnic ice chest containing a Gerbrands pellet dispenser (45 mg Noyes pellets), Gerbrands lever, and dc lights. The animals were maintained at 80% of free-feeding weight, earning their

---

[1]This research was supported by United States Public Health Service Grant B3861, Atomic Energy Commission Contract AT(11-1) 1201, and United Cerebral Palsy. Reprints may be obtained from the author, Dept. of Pathology, The University of Michigan, Ann Arbor, Mich., 48104.

[2]The P. J. Noyes Co., Lancaster, New Hampshire. Lab. rat food pellet (standard formula): Purina Lab-Chow 80.0%, Bleached Flour 8.0%, Dry Milk Solids 2.0%, Glucose Solids 7.5%, Gelatin 1.5%, Tricalcium Phosphate 1.0%.

entire food ration in daily experimental sessions. No water deprivation was imposed at any time. Water was available in the home cage from a calibrated drinking tube, and during the experimental session from a spout (bent stainless steel tube No. 1204, Acme Metal Products, Inc.) fitted to a calibrated reservoir which was clipped to the side of the ice chest 90° to the left as the animal faced the work panel. The spout was accessible through a slot cut in a Micarta panel. Licks at the water spout were recorded electronically. Apparatus for control and recording was housed in an adjoining room.

The animals were reduced to 80% body weight and placed in the experimental space. The apparatus was programmed to operate the pellet magazine once each minute (mag training), and when lever-pressing occurred, each press delivered a pellet (CRF). When each pellet was reliably seized and eaten upon delivery, the magazine was operated only once every 1.33 min. After several bar-presses had been reinforced, operation of the maga-

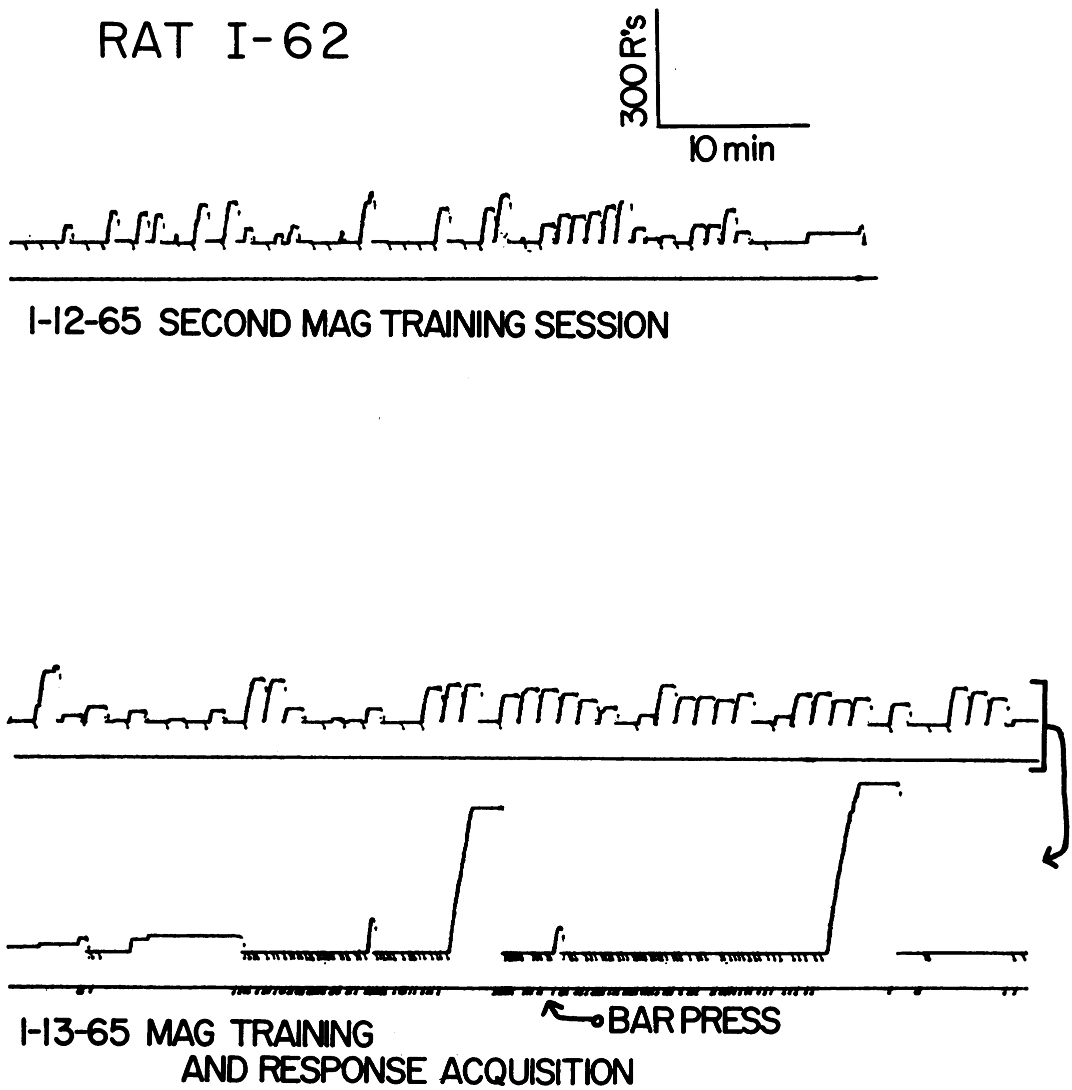

Fig. 1. Two successive sessions showing development of post-pellet drinking bursts during mag training and disappearance of burst pattern upon acquisition of CRF behavior. Licking steps recorder cumulatively, and pellet delivery resets recorder and makes vertical hatch mark. Bar-pressing shows as vertical hatch marks on lower (event) channel.

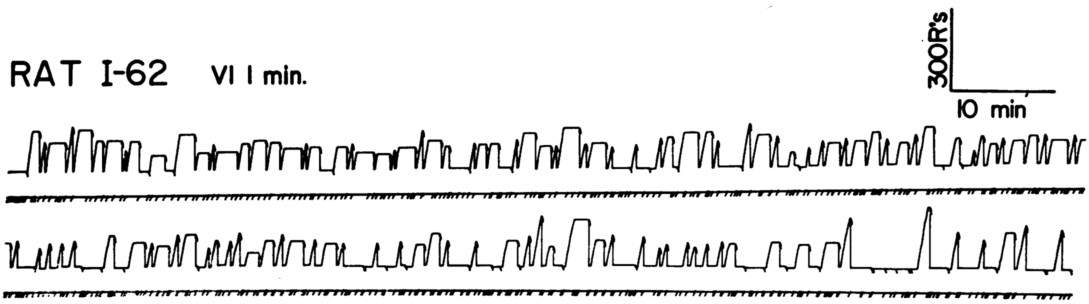

Fig. 2. Typical record of a complete session (3.5-hr) showing production of polydipsia by the VI 1 min schedule. Licking steps recorder cumulatively, and pellet delivery resets recorder and makes vertical hatch mark. Bar-pressing shows as vertical hatch marks on lower (event) channel.

zine by the 1.33-min clock was discontinued. I-61 and I-62 were given five CRF sessions limited to 200 pellets per daily session, and then transferred to a VI 1 min schedule for 3.5-hr daily sessions. On VI 1 min, a bar-press produced a pellet on the average of once per minute, but the actual intervals were programmed to vary between 2 sec and 2 min. Rat I-70 was given 40 sessions on CRF before being transferred to the VI 1 min contingency.

Results

Two of the three animals (I-61, I-62) developed a polydipsic drinking pattern during mag training. The upper portion of Fig. 1 shows the second day that I-62 was exposed to the apparatus. Each pellet delivery reset the recorder and made a vertical hatch mark. Licks at the water spout step the recorder vertically and cumulatively. Late in the second mag training session a fairly regular pattern of post-pellet drinking developed. The lower portion of Fig. 1 shows that this pattern continued in the next day's session until the first few bar-presses (lower trace) were emitted. At that point the mag training clock was turned off and the animal obtained pellets on the CRF schedule. It is evident that with acquisition of bar-pressing, and the consequent increase in pellet-delivery frequency, the post-pellet drinking pattern immediately ceased. Later, when this animal was switched to the VI 1 min schedule, the post-pellet drinking pattern returned (Fig. 2).

Figure 3 further illustrates the control of drinking pattern by inter-pellet time. Three consecutive daily sessions are shown. At the top are sessions 39 and 40 on CRF; the lower portion is the first VI 1 min session and shows development of the polydipsic pattern. Later sessions showed the typical pattern regularity seen in Fig. 2.

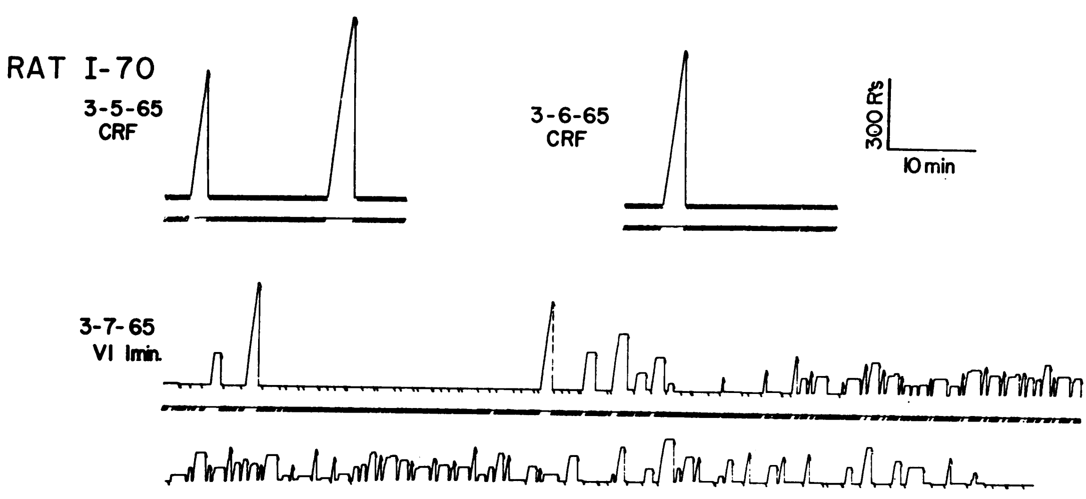

Fig. 3. Transition from CRF to VI 1 min showing development of post-pellet licking bursts.

EXPERIMENT 2

Subjects

Two female, littermate rats of the Hisaw strain, designated HI-9 and HI-10, were used. They were five months old at the start of the experiment, and weighed 250 and 275 g, respectively. Housing conditions were as in Exp 1.

Procedure

The animals were reduced to 80% of starting weights by limiting daily food intake and then trained in a two-lever experimental space. Water was not freely available in this apparatus but was in the home cage. In the first training phase, one lever produced Noyes food pellets (45 mg) on CRF, and the second yielded 0.1 ml water from a Gerbrands Dipper Feeder on CRF. Both levers (Gerbrands Rat Lever) were mounted on a front work panel with metal shields separating them to prevent simultaneous responding. To the right of the right-hand lever was the pellet receptacle, and to the left of the other lever was an opening into which the water dipper rose. After several sessions on CRF for food pellets, the animals' home-cage water tubes were removed and training on the water-producing lever was instituted. This was complete within a few days and home-cage water was then restored for the remainder of the experiment. This was the first instance in which any water deprivation was used in connection with schedule-induced polydipsia, and this was in effect only to shape the bar-pressing response.

In the next phase, the schedule was changed to: concurrent VI 1 min (pellets), FR 2 (water). Daily experimental sessions were set for 3.5 hr. Water intake was measured as the difference between initial and remaining volume in the water container immediately after the session, with a correction for evaporation determined from 10 blank sessions. Cage water intake was measured daily. Any food supplements necessary to maintain the animals at 80% body weight were given immediately after the daily session.

Several sessions were given at the following FR (water) values in the ascending order shown: FR 2, 5, 10, 20. Rat HI-10 was given sessions at FR 30 and FR 50 as well. One control or counterproof procedure was run after the FR 10 series: concurrent VI 1 min (pellets), FR 10 (no water). The dipper solenoid was activated for the reinforcement cycle (4 sec) and the dipper rose into position, but no water was delivered.

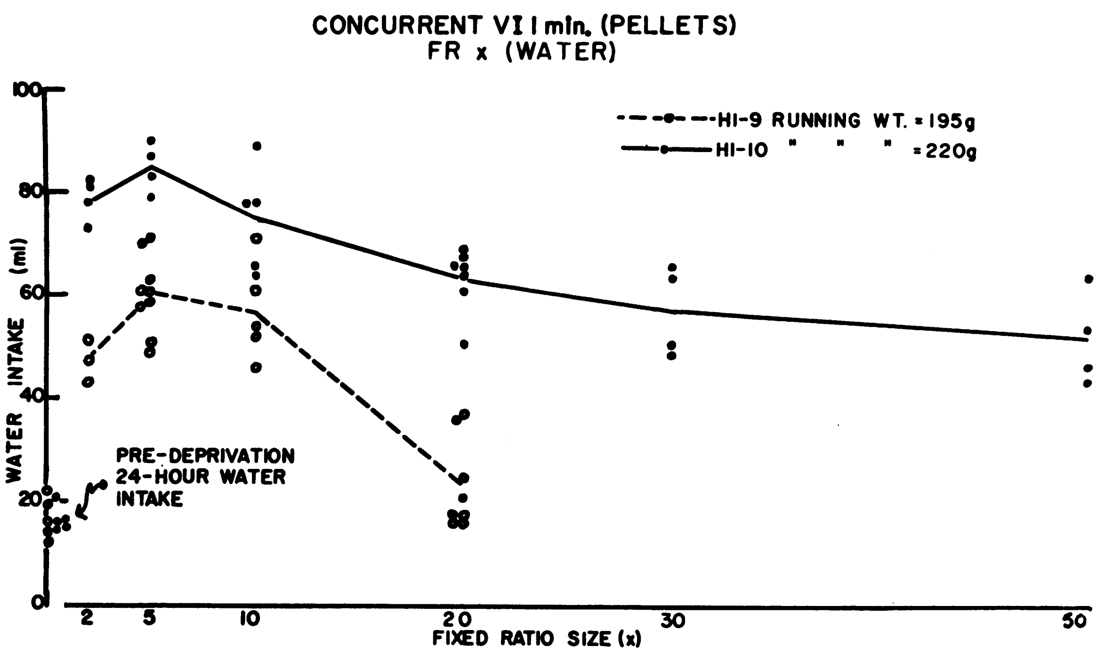

Fig. 4. Level of polydipsia under VI 1 min (pellets) as a function of FR size (0.1 ml water portions). For comparison, five pre-experimental days of 24-hr water intake are plotted near the y-axis for both animals.

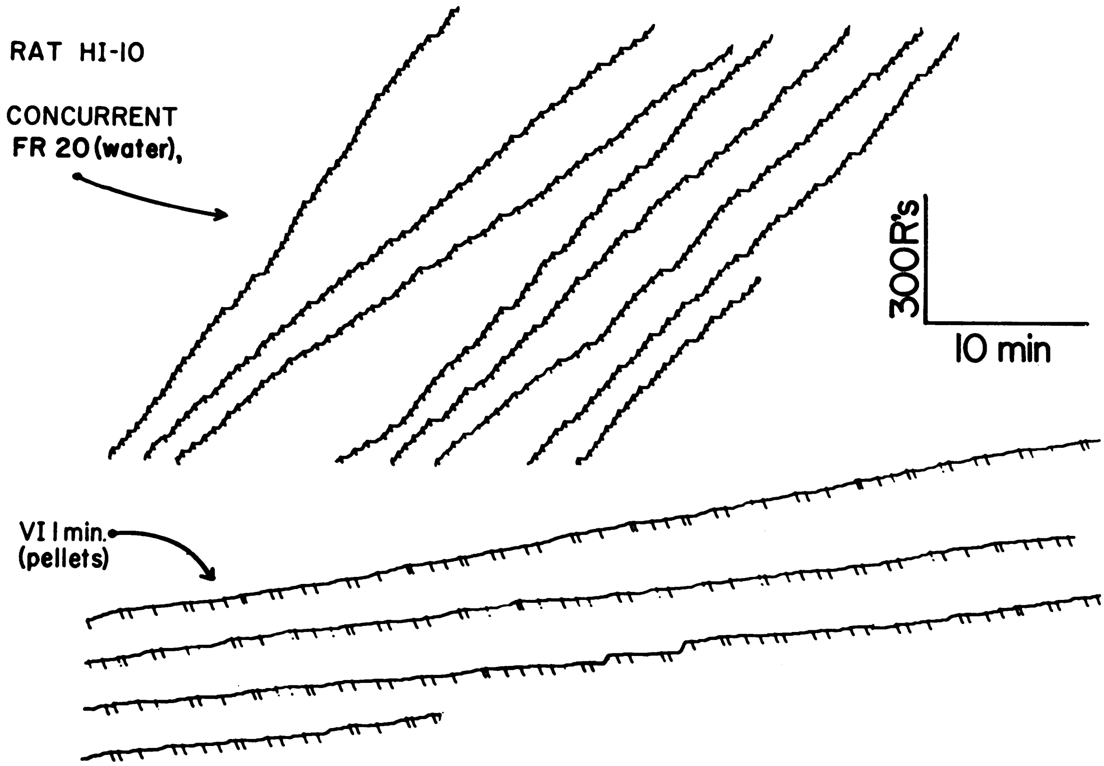

Fig. 5. Representative session for Rat HI-10, concurrent VI 1 min (pellets), FR 20 (water). Delivery of water or pellets indicated as vertical hatch mark on their respective records. Bar-pressing steps recorders cumulatively.

Results

Figure 4 shows the session water intake as a function of FR size for both animals. As in the case of VI 1 min (pellets) with a freely-available water tube (Falk, 1961a), schedule-induced polydipsia was produced. Rat HI-10 sustained a polydipsic level even at FR 50, while the intake of HI-9 fell to the normal pre-deprivation, 24-hr level at FR 20. Home-cage water intake remained negligible for both animals (1-2 ml per 24 hr).

A typical record is shown in Fig. 5. Ratio behavior is maintained throughout the session. There is occasional breaking of a ratio and a few short pauses between ratios. At a few places in the VI record, local high rates are revealed which are probably the result of FR induction.

In the counterproof procedure (Bernard, p. 55 ff) shown in Fig. 6, responding soon ceases on the FR component when the responses produce the dipper, but not the water. Rat HI-9 yielded a similar counterproof record.

DISCUSSION

Experiment 1

The development of polydipsia during mag training demonstrates, as did the previous work with free VI 1 min (Falk, 1961b), that post-pellet drinking does not depend upon any displacement of activity from an operant such as bar-pressing to licking at a water spout. A long history of CRF sessions does not prevent the rapid development of polydipsia upon switching to VI 1 min. Clearly, the consumption of Noyes pellets on a long enough inter-pellet time (Falk, 1966b) is a sufficient condition to produce polydipsia.

Experiment 2

The major finding is that schedule-induced polydipsia will develop not only when water is freely available concurrently with a food-pellet VI 1 min schedule, but also under food-pellet VI 1 min when water is available concurrently only in discrete portions under an FR contingency. The level of polydipsia attained in ml per 3.5-hr session was of the

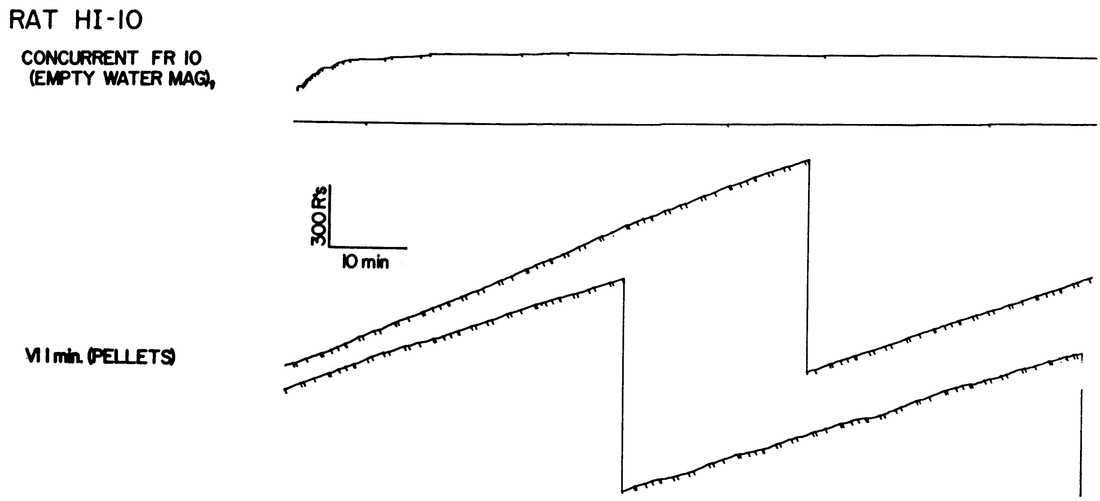

Fig. 6. Counterproof session showing disappearance of FR behavior when dipper no longer delivers water.

same order as that attained under the VI 1 min (pellet) condition when the water was freely available (Falk, 1961a). The polydipsia, then, is more than a simple "time-filler", mediating response, or displacement activity. It has motivating properties sufficient to sustain FR behavior for an entire session.

To say that polydipsia has motivating properties is not to reify polydipsia. This may be illustrated by an example from another area of behavioral research. Azrin, Hake, Holz, and Hutchinson (1965) note the common observation that punishment often produces escape responses. Further, they were able to sustain FR behavior on a second response key which provided escape from punishment (shock) of food-key responses. Punishment, then, "establishes motivation to escape from the punishment situation." Likewise, Exp 1 demonstrated that VI 1 min (pellets) produces polydipsia. In Exp 2 FR behavior on a second lever established the motivational properties of polydipsia, just as Azrin *et al.* (1965) established "a direct confirmation of the existence of . . . escape motivation." Not only is VI 1 min (pellets) a condition producing polydipsia, it also elicits a polydipsia which is reinforcing, *i.e.*, polydipsia will sustain substantial fixed ratios. To state that it is the water which is reinforcing in this situation locates the property of reinforcement in the stimulus rather than as a relation between independent response rates (Premack, 1959), *viz.* bar-pressing of the second lever and polydipsia. In an experiment such as that of Azrin *et al.* (1965), one does not name the absence of shock "the reinforcement" but there is a temptation to do this with a commodity such as water. In the example given below, is it the provision of another pigeon or the aggressive behavior which sustains the FR behavior?

The concurrent polydipsia induced by certain properties of intermittent food schedules is perhaps akin to the aggressive behavior observed by Azrin (1964) concurrent with S^{Δ} periods. Both types of behavior have been shown to have motivating properties and be functions of certain concurrently operating schedule parameters. In pigeons, Azrin was able to maintain FR behavior on a second key during food S^{Δ} periods, the reinforcing event being the provision of another pigeon which the first bird then attacked. Such extra, unprogrammed phenomena as polydipsia and aggression, which are produced by the environmental controls imposed by certain behavior schedules, and are prepotent enough to sustain scheduled behavior in their own right, have been termed "adjunctive behaviors" (Falk, 1966b).

The counterproof procedure ruled out the possibility that some feature of the environment other than water was sustaining the FR behavior. If, for example, operation of the dipper had become part of an adventitiously reinforced chain with responses on the VI food-producing lever as a final member, then one would expect only minor disruption of the FR when water was removed, and more serious variations in VI rate. In fact, FR behavior all but ceased and the VI was not disrupted. The FR channel under the counterproof procedure is reminiscent of a simple extinction record, and does not seem essential to any aspect of the VI behavior.

REFERENCES

Azrin, N. H. Aggression. Paper read at Amer. Psychol. Ass., Los Angeles, Sept., 1964.

Azrin, N. H., Hake, D. F., Holz, W. C., and Hutchinson, R. R. Motivational aspects of escape from punishment. *J. exp. Anal. Behav.*, 1965, **8**, 31-44.

Bernard, C. *An introduction to the study of experimental medicine*. New York: Dover Publ., 1957. (originally published 1865).

Falk, J. L. Production of polydipsia in normal rats by an intermittent food schedule. *Science*, 1961a, **133**, 195-196.

Falk, J. L. The behavioral regulation of water-electrolyte balance. In M. R. Jones (Ed.), *Nebraska symposium on motivation:* 1961. Lincoln: Univer. Nebraska Press, 1961b. Pp. 1-33.

Falk, J. L. Studies on schedule-induced polydipsia. In M. J. Wayner (Ed.), *Thirst: first international symposium on thirst in the regulation of body water*. New York: Pergamon Press, 1964, Pp. 95-116.

Falk, J. L. Schedule-induced polydipsia as a function of fixed interval length. *J. exp. Anal. Behav.*, 1966, **9**, 37-39.

Premack, D. Toward empirical behavior laws. I. Positive reinforcement. *Psychol. Rev.*, 1959, **66**, 219-233.

Stein, L. Excessive drinking in the rat: Superstition or thirst? *J. comp. physiol. Psychol.*, 1964, **58**, 237-242.

Received April 19, 1965