Transformation of polydipsic drinking into operant drinking: A paradigm? ¹

EVALYN F. SEGAL, *University of Illinois at Chicago Circle, Chicago, Ill. 60680*

Polydipsia in a rat, induced by spacing of small food portions, spontaneously evolved into an operant drinking response, adventitiously reinforced by food deliveries. As operant control became stronger, the inductive control of food over polydipsic drinking disappeared. The final form of the behavior responded to amphetamine in the same way that other moderate-rate operants do, and unlike the way polydipsia does. The present, unprogrammed result suggests one origin of operant behavior, and suggests that there is a range of behavior between simple reflexes and operants.

In the course of an experiment on the relation of bar-press reinforcement schedules to schedule-induced polydipsia, a single rat was noticed to change its pattern of drinking in a direction somewhat resembling the typical pattern of operant behavior under the prevailing fixed-interval reinforcement schedule. At that point, a series of experimental manipulations was undertaken to follow the transformation of polydipsia into operant drinking. This paper describes the manipulations and results. Because experimental changes occurred frequently, the method will be described along with the results.

METHOD AND RESULTS

The S was one young adult male hooded rat, maintained at 80% of ad lib weight by food deprivation, and exposed to a succession of food schedules in sessions of variable length, in a Plexiglas chamber that included a bar, a food cup delivering 45-mg Noyes rat chow pellets, and a water bottle

with a metal drinking spout extending into the chamber, attached to a Grason-Stadler drinkometer. The chamber was not sound- or light-insulated, but was housed in a sound-insulated room, isolated from control and recording apparatus. The room was well lit, and a closed-circuit television hook-up permitted continuous observation of the rat on a viewing screen in the control room.

Over the first seven sessions, the rat was exposed to a schedule of free (noncontingent) 45-mg pellet deliveries spaced 30 sec apart (total of 30 pellets), then 60 sec (110 pellets), then 90 sec (85 pellets). The mean number of water licks per pellet, expressed to the nearest whole number, rose gradually from 1 in the first session to 68 in the seventh session, indicating the gradual development of polydipsia.

In the eighth session, the rat was shaped by hand to bar press for pellet reinforcement, and over the next 15 sessions (Sessions 9-23) was exposed successively to fixed-interval (FI) bar-press reinforcement schedules of 1 min (total of 65 pellets), 1.5 min (200 pellets), 2 min (340 pellets), and 3 min (65 pellets). By Session 21, on FI 2 min, the rat was showing the typical polydipsic drinking pattern (see top tracing, Fig. 1): a (brief) drink after the arrival of each food pellet. Each drink was followed by an accelerated episode of bar pressing until the next pellet arrived, a pattern characteristic of FI reinforcement schedules. The mean number of water licks per pellet over Sessions 18-20 (FI 2 min) was 35, and of bar presses, 11.

Midway through Session 21, the drinking pattern started to change. At the first two check marks over the top tracing in Fig. 1, licks happened to occur shortly before the

next food pellet arrived. A little later, licks occurring toward the end of the fixed interval became more common, and also the number of licks in each postpellet polydipsic drinking burst rose. By the end of Session 21, there was an episode of accelerated-rate licking toward the end of almost every interval. The record for Session 21, then, shows the rather sudden, and unprogrammed, transformation of purely polydipsic, pellet-induced drinking into a new behavior pattern that was a combination of polydipsic drinking—the steady-rate burst just after food delivery, and operant drinking—the accelerated-rate licking burst just before the next food delivery. The mean number of licks and bar presses per pellet in this session was 109 and 13, respectively.

In the next, 22nd, session, the bar-press reinforcement schedule was lengthened to FI 3 min to "bring out" the FI-like pattern of licking. The third tracing in Fig. 1 shows the continuation of this schedule into the first part of the next, 23rd, session. The FI-like licking pattern was now much more pronounced. After 15 pellets, the schedule was changed to free food every 180 sec, in order to see if the FI-like licking pattern depended on the FI schedule of bar-press reinforcement. The last two tracings in Fig. 1 show that eliminating the contingency between bar presses and reinforcement neither reduced the amount of licking nor abolished the FI-like licking pattern. In fact, the total amount of licking, both polydipsic and FI-like, increased. The mean number of licks and bar presses per pellet over this session was 163 and 16, respectively.

During Sessions 23-31, the free-food schedule continued, first at a spacing of 180 sec (215 pellets), and then at a spacing of 240 sec (425 pellets). Figure 2 shows the licking performance in Session 31, where the food spacing was 240 sec. Although the pattern of polydipsic followed by FI-like

Fig. 1. Upper tracing in each record shows cumulative water licks, the tracing below it, bar presses. Pellet arrivals reset the cumulative pen to baseline. Top two sets of tracings: Records from Session 21, bar presses reinforced on FI 2 min. First 31 pellets of the 150-pellet session omitted. Check marks note intervals in which licking occurred shortly before pellet arrival. Bottom two sets of tracings: Session 23. In A, bar presses were reinforced on FI 3 min. In B, food was automatically delivered every 180 sec.

Fig. 2. Session 31 (last nine food deliveries of the 75-pellet session omitted). Food automatically delivered every 240 sec.

drinking continued, there began to be episodes where no polydipsia occurred, that is, where drinking did not follow immediately after food ingestion but only after a delay, as at a, b, c, and d. At the same time, the amount of bar pressing was much diminished, indicating that the rat was sensitive to the elimination of the contingency between bar presses and food. The mean number of licks and bar presses per pellet in Session 31 was 239 and 6, respectively.

In the second half of Session 35, the schedule was changed to FI 4 min for bar presses. This FI 4-min schedule was in effect during most of the remaining sessions (35-52), except for occasional shifts back to the 240-sec free-food schedule. In every case, bar pressing increased under the FI schedule and decreased under the free-food schedule, while the amount of licking remained about the same.

The top tracings in Fig. 3 show the final stage of drinking and bar pressing under FI 4 min. Polydipsic drinking had completely disappeared, to be replaced by a temporal pattern of drinking indistinguishable from that of the explicitly reinforced bar pressing. (But note the difference in scale of the two responses.) The mean number of licks and bar presses per pellet in Session 37 was 108 and 18, respectively.

Just before Session 50, 4 mg/kg d-amphetamine sulfate was injected intraperitoneally. Amphetamine is known to increase operant responses of low to moderate rate, but to decrease polydipsic, as

well as normal thirst, drinking (Falk, 1964; Segal & Deadwyler, 1964; Segal & Oden, 1968; Segal, Oden, & Deadwyler, 1965b; Teitelbaum & Derks, 1958). The drug session, therefore, was a test of whether the accelerated-rate drinking pattern would respond to drug as operants do or as polydipsia does. The test was run under the FI 4 min bar-press reinforcement schedule. The results of the drug test appear in the bottom tracings of Fig. 3. Both bar presses and licks increased under drug, and for both, the FI-like response pattern was preserved. The average number of licks per pellet in the predrug, drug, and postdrug sessions was 125, 180, and 120. The corresponding data for bar presses were 14, 37, and 25. The comparable drug response of drinking and bar pressing suggests that the drinking was by this time wholly operant.

DISCUSSION

Schaeffer & Salzberg (1967) have also reported a case where polydipsia in a single rat appeared to evolve into operant drinking under the reinforcement control of food delivery. It was not clear in their report, however, whether drinking had become exclusively operant, as in the final stage of this experiment, or whether it was in some intermediate stage, as in the earlier stages of the present experiment. [Also see Segal, Oden, & Deadwyler (1965a) for what may have been another case of polydipsia that was in the process of evolving into an operant.]

Polydipsia is interesting as an example of

what may be a large class of "induceable" behavior patterns. Falk (in press) has likened polydipsia to the displacement behavior studied by ethologists. Other induceable behavior appears to include aggression and copulation, both induceable by spaced electric shocks (Azrin & Hutchinson, 1967; Azrin, Hutchinson, & Hake, 1966, 1967; Ulrich, in Kimble, 1967; Barfield & Sachs, 1968); wheel running, induceable by food spacing (Levitsky, 1967; Segal, 1969); and "distress" vocalizations, induceable by removing young animals from their mothers (Hoffman, Schiff, Adams, & Searle, 1966). Although these responses appear to be elicited by specific stimuli, they do not appear to be simple reflexes, because they involve complexly organized skeletal behavior and because they do not commonly appear on first exposure to the eliciting stimuli. On the other hand, they do not appear to be simple operants, because they are elicitable, and because they are not under the control of reinforcement contingencies at the time that they appear as induced responses. However, it does seem that such complexly organized, induced skeletal behavior is susceptible to operant reinforcement contingencies, and may indeed represent an important class of raw material out of which operants are shaped. (See Skinner, 1966, for a related discussion.)

Miller and his associates have lately shown that many reflexes can be modified by their consequences, and so be classed as "partially operant." [See Miller (1969) for a review of these studies.] The degree of control by reinforcement contingencies in these cases is still small, however, relative to the reflexive control that continues to be exerted over such responses by their customary eliciting stimuli, and relative to the freedom of control by eliciting stimuli seen in most operants, and, interestingly, in the final form of drinking seen in the present experiment. It may be that there is a wide range between clearly reflex and clearly

Fig. 3. Left: Cumulative bar presses. Right: Cumulative water licks. Pellet arrivals reset both pens to baseline. Top: Last 14 of 75 food deliveries of Session 37. Bar presses reinforced on FI 4 min. Bottom: All but the last 3 of 75 food deliveries in Session 50. Bar presses reinforced on FI 4 min. 4 mg/kg d-amphetamine injected just before the session.

operant behavior, and that responses occurring at intermediate points in this range will show varying strengths of relationship to eliciting stimuli, on the one hand, and reinforcement contingencies, on the other.

REFERENCES

- AZRIN, N. H., & HUTCHINSON, R. R. Conditioning of the aggressive behavior of pigeons by a fixed-interval schedule of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 395-402.
- AZRIN, N. H., HUTCHINSON, R. R., & HAKE, D. F. Extinction-induced aggression. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 191-204.
- AZRIN, N. H., HUTCHINSON, R. R., & HAKE, D. F. Attack, avoidance, and escape reactions to aversive shock. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 131-148.
- BARFIELD, R. J., & SACHS, B. D. Sexual behavior: Stimulation by painful electrical shock to skin in male rats. *Science*, 1968, 161, 392-395.
- FALK, J. L. Studies on schedule-induced polydipsia. In M. J. Wayner (Ed.), *Thirst*. New York: Macmillan, 1964. Pp. 95-116.
- FALK, J. L. Conditions producing psychogenic polydipsia in animals. *Annals of the New York Academy of Sciences*, in press.
- HOFFMAN, H. S., SCHIFF, D., ADAMS, J., & SEARLE, J. L. Enhanced distress vocalization through selective reinforcement. *Science*, 1966, 151, 352-354.
- LEVITSKY, D. A. Psychogenic wheel running. *Psychonomic Bulletin*, 1967, 1, 35. (Abstract)
- MILLER, N. E. Learning of visceral and glandular responses. *Science*, 1969, 163, 434-445.
- SCHAEFFER, R. W., & SALZBERG, C. L. Schedule-induced polydipsia: An atypical case. *Psychological Reports*, 1969, 20, 1071-1076.
- SEGAL, E. F. The interaction of psychogenic polydipsia with wheel running in rats. *Psychonomic Science*, 1969, 14, 141-144.
- SEGAL, E. F., & DEADWYLER, S. A. Amphetamine differentially affects temporally spaced bar pressing and collateral water drinking. *Psychonomic Science*, 1964, 1, 349-350.
- SEGAL, E. F., & ODEN, D. L. Concurrent facilitation of food-reinforced spaced licking and depression of schedule-induced, polydipsic licking by amphetamine. *Psychonomic Science*, 1968, 10, 155-156.
- SEGAL, E. F., ODEN, D. L., & DEADWYLER, S. A. Determinants of polydipsia: IV. Free-reinforcement schedules. *Psychonomic Science*, 1965a, 3, 11-12.
- SEGAL, E. F., ODEN, D. L., & DEADWYLER, S. A. Determinants of polydipsia: V. Effect of amphetamine and pentobarbital. *Psychonomic Science*, 1965b, 3, 33-34.
- SKINNER, B. F. The phylogeny and ontogeny of behavior. *Science*, 1966, 153, 1205-1213.
- TEITELBAUM, P., & DERKS, P. The effect of amphetamine on forced drinking in the rat. *Journal of Comparative & Physiological Psychology*, 1958, 51, 801-810.
- ULRICH, R. E. Pain-aggression. In G. A. Kimble (Ed.), *Foundations of conditioning and learning*. New York: Appleton-Century-Crofts, 1967. Pp. 600-622.

NOTE

1. This work was supported by Grants GB 1605, GB 5777, and GB 7292 from the National Science Foundation, and Grant NIMH 8505 from the National Institute of Mental Health. The experiment was done in the laboratory of Professor John Vane, Department of Pharmacol-

ogy, Royal College of Surgeons of England, London. I thank Professor Vane and Professor Gustav Born, head of the department, for their

hospitality, and Sergio Ferreira, Isabel Mills-Fenn, Zygmunt Sabikowski, and Margret Tonnesmann for their help.

Maternal aggression: A failure to replicate¹

RUSSELL REVLIS and K. E. MOYER,
Carnegie-Mellon University, Pittsburgh, Pa.
15213

Endroczi et al (1958) reported that only lactating rats in the presence of their young would kill frogs. This "maternal aggression" could be suppressed by injections of oestrone. No aspect of that study was confirmed in the experiments reported here. Nonfrog-killing rats were not induced to kill by lactation and the presence of their young. A significant number of naive virgin female rats did kill frogs and the frog-killing response was not suppressed by oestrone.

The tendency for females of many species to behave aggressively toward any intruder during the period that they are nursing young is a well recognized but little investigated phenomenon (Beach, 1948, p. 99; Barnett, 1968). It has been suggested by Moyer (1968) that maternal aggression is one of several kinds of aggressive behavior and that it has a physiological basis which is distinct from other types of aggression. Some support for the unique physiological basis of this particular kind of aggression is provided by the experimental work of Endroczi, Lissak, & Telegdy (1958). They indicate that frog-killing behavior in the albino rat is specific to the lactating mother, in her home cage, and with her litter present. This behavior showed a gradual suppression with the weaning period of the litter.² According to these authors, neither male rats, nor nonlactating female rats will attack a frog placed in its cage. It was further demonstrated (Endroczi et al, 1958) that the maternal aggression of the rat was

dependent on a particular hormone balance. Oestrone treatment for 10 days eliminated frog killing without interfering with the care of the young, and the suppressive effects of the oestrone on frog killing could be reversed by injections of hydrocortisone. The descriptive nature of these data preclude a more quantitative analysis of the treatment effects.

This study is an attempt to replicate the above findings with more precise measures of aggressive behavior.

EXPERIMENT 1

Subjects

Eleven female albino rats (Sprague-Dawley), between 95 and 110 days of age, were used. Stimulus animals were a frog (*Rana pipiens*, female, 76 mm long) and a female albino mouse.

Apparatus

Subjects lived in standard Hoeltge cages (7 x 7 x 9.5 in.) with a Plexiglas top through which E could make observations. Latencies and response durations were recorded on a multipen event recorder which was activated by a panel of switches controlled by E.

Procedure

Subjects were adapted to the cages for 48 h and then given a 7-min pretest with the stimulus animals. Each S was presented with a frog and a mouse. The order of presentation was counterbalanced across the S population but remained constant for each rat for both the pre- and posttest conditions. The interval between presentations was 3-5 min. The following behavioral measures were made during test periods: (a) duration of sniffing of the stimulus animal (S faced the stimulus animal at a distance of less than 2 in. and simultaneously moved its whiskers

Table 1

Entries are in seconds except for investigation which was calculated in terms of per cent of time investigating prior to kill because Ss could have killed with different latencies.

	Measures taken prior to pregnancy and after parturition						
	Frog Means		t		Mouse Means		t
	F	Pre	Post	t	Pre	Post	t
Latency 1st Bite	46.0*	377.7	183.6	3.18*	402.7	75.0	10.61*
Biting Duration	9.4**	.3	28.0	2.68**	.6	5.3	2.49**
Investigation	5.0**	4.5%	8.3%	2.04	17.5%	29.4%	1.77

* $p < .01$

** $p < .05$