EFFECTS OF RESPONSE-DEPENDENT AND INDEPENDENT ELECTRIC SHOCK ON SCHEDULE-INDUCED POLYDIPSIA

NORMAN HYMOWITZ¹ AND EARL X. FREED

STATE UNIVERSITY COLLEGE AT BUFFALO AND THE ALCOHOL RESEARCH LABORATORY, VA HOSPITAL, LYONS, NEW JERSEY

In Experiment 1, lever pressing by rats was maintained by the delivery of food pellets under a 45-sec fixed-interval schedule. Fixed-time 180-sec and fixed-interval 180-sec schedules of shock delivery were systematically superimposed on the baseline food schedule to study effects on schedule-induced water intake. Response-dependent shock had little, if any, effect on water intake, whereas shocks independent of lever pressing attenuated fluid intake. In Experiment 2, rats received food pellets under a fixed-time 60-sec schedule. Electric shock delivered concurrently under a variable-time 180-sec schedule, but never while the animal was licking or within 5 sec after licking terminated, led to similar attenuation of water intake. These findings suggest that schedule-induced polydipsia is sensitive to differences in the functional properties of response-independent and dependent electric shock.

Schedule-induced polydipsia denotes excessive fluid consumption in non-fluid deprived animals during exposure to intermittent food schedules (Falk, 1961). Variables of which schedule-induced polydipsia is a function are the frequency of food reinforcement (Falk, 1966; Flory, 1971; Freed and Hymowitz, 1972), degree of body weight loss (Falk, 1969; Freed and Hymowitz, 1972), magnitude of the food pellet or meal (Falk, 1967; Flory, 1971; Freed and Hymowitz, 1972), and nature of the food pellet (Falk, 1971; Freed, 1971b).

Recent studies (Dunham, 1971; Freed, 1971a; Segal and Oden, 1969) described the effects of electric shock on polydipsia. Segal and Oden (1969) reported an increase in licking when mild, response-independent foot shock was delivered. Licking remained elevated after shock was removed, and the data were interpreted as indicating the enhancement of polydipsia by a non-specific emotion-arousing stimulus. Dunham (1971) reported a similar increase in licking following delivery of response-dependent shock of sufficient in-

tensity (0.20 mA, 1.0-sec duration) to suppress lever pressing. Freed (1971a), on the other hand, reported a decrease in licking with more intense (0.5 mA, 0.5-sec duration) response-dependent shock.

Although these reports describe interesting relationships between schedule-induced polydipsia and electric shock, they leave many questions unanswered. For example, data on shock intensity, and on the role, if any, of the dependency of shock delivery on lever pressing are not available. The present studies compared the effects on polydipsia of a wide range of intensities of response-dependent and independent electric shock.

GENERAL METHOD

Subjects

Three female Long Evans hooded rats, 200 to 250 g, and two male albino Sprague-Dawley rats, 250 and 290 g, served in Experiments 1 and 2, respectively. The animals were housed individually and were maintained at 80% of initial free-feeding weight on Purina Laboratory Rat Chow with water freely available in the home cage.

Apparatus

A Grason-Stadler sound-attenuated operant rat chamber, Model E3125A-300, was used in Experiment 1, and a BRS Foringer operant

¹Experiment 2 was supported by the State University of New York Research Foundation Grant-in-Aid and Fellowship, 0434-03-021-72, to Norman Hymowitz. Reprints may be obtained from Norman Hymowitz, Department of Psychiatry, New Jersey College of Medicine and Dentistry, 100 Bergen St., Newark, N.J. 07103. INTERIMS, Room 1307.

rat chamber, RC-002, was used in Experiment 2. In each case, water was available within the operant chamber from a stainless steel spout accessible from a slot cut in the chamber wall. The spout was connected to a calibrated cylinder and Grason-Stadler drinkometer located outside of the chamber. Counters and cumulative recorders recorded the data.

Electric shock to the grid floor and response lever was provided by a Grason-Stadler shock generator (Model E607B) and grid scrambler in Experiment 1, and by a BRS-Foringer shock generator (Model SG-901) and grid scrambler in Experiment 2. Noyes laboratory rat-food pellets (0.045 g) were used as reinforcers.

Procedure

After 15 to 25 sessions under an intermittent food schedule, described separately for each experiment, electric shock was introduced. Blocks of concurrent food-and-shock sessions alternated with blocks of food-alone sessions. Shock intensity was increased between blocks of shock sessions, but shock duration remained constant (0.5 sec). Standard houselights and white masking noise were on during experimental sessions. Each session terminated with receipt of 40 food pellets.

EXPERIMENT 1

Procedure

After lever-press training, two 100-pellet sessions on a fixed-ratio one (FR 1) schedule, and 20 sessions under a fixed-interval 45-sec (FI 45-sec) food schedule, three female rats were exposed to concurrent fixed-time 180-sec (FT 180-sec) shock and FI 45-sec food schedules. The schedules did not begin together in phase so that there was no consistent relation between them. A block of five successive sessions of concurrent food and shock alternated with a block of three successive sessions of food alone. Shock intensity ranged from 0.25 mA to 0.80 mA. All changes in shock intensity were made between blocks of five shock sessions. Each animal was then exposed to its highest shock intensity for 10 successive sessions to observe response recovery.

Ten FI 45-sec sessions preceded the study of response-dependent shock and polydipsia. Three successive sessions of relatively mild (0.25 and 0.30 mA) response-dependent shock introduced the dependency of shock on lever

pressing. Five blocks of sessions under concurrent FI 45-sec food and FI 180-sec shock schedules alternated with blocks of three successive FI 45-sec food sessions. During concurrent sessions, shock intensity ranged from 0.25 to 0.50 mA. Shock intensity was constant within a given block of shock sessions.

For Rats E-1 and E-2, the study of response-dependent shock delivery was followed by a study in which 5.6% w/v alcohol served as the available fluid. Fifteen baseline (FI 45-sec food) sessions with alcohol preceded a series of sessions in which the effects of response-independent shock on polydipsia was repeated with alcohol as the available fluid. The animals were then exposed to response-independent shock with water as the sole fluid. Following a block of five FI 45-sec food baseline sessions, blocks of five concurrent food-and-shock sessions alternated with blocks of three food-alone sessions. Animal E-3 was not studied under alcohol and instead received only additional food-and-shock sessions.

RESULTS

Figures 1 and 2 show mean water intake and responses, respectively, under each experimental treatment. Despite differences in baseline fluid consumption and shock intensities employed, the overall pattern of results is similar for each rat. Shock delivered independently of responding led to marked attenuation of water intake; the higher the shock intensity, the greater the attenuation. Water intake returned to baseline levels when the shock was omitted, and for E-1 and E-3, recovery of water intake occurred during successive exposures to 0.40-mA and 0.50-mA shock, respectively. More intense shock, however, further attenuated water intake.

Response-dependent shock of comparable intensities had little consistent effect on water intake. Lever pressing, however, was disrupted more than during response-independent shock. When the shock was removed, lever pressing once more increased.

Figure 3 shows cumulative records for E-1, which are representative of all of the animals. The attenuation of water intake under response-independent shock was due to the omission of some, and the shortening of other licking episodes. Lever pressing was only slightly affected, and the animals continued to ingest food pellets as soon as they were

Fig. 1. Mean water intake for each animal during baseline (B) and shock conditions of Experiment 1. The initial B-point represents the mean for Sessions 16 to 20 of acquisition, subsequent B-points represent the mean of the successive baseline sessions. Shock points represent the mean of five successive shock sessions at a constant shock intensity. Asterisks indicate conditions in which the animal was not studied.

delivered. In contrast, during response-dependent shock, the animals continued licking, although lever pressing was disrupted.

For E-2, mean water intake during baseline was initially very low (Figure 1). During the study, water intake increased and stabilized at a higher baseline level. The reasons for this shift were unclear. It should be noted, however, that E-2 displayed consistent schedule-induced licking patterns. Apparently, this animal was able to emit a large number of licks without consuming much water. Since licking remained relatively stable from one block of baseline sessions to the next, the shift in baseline water intake presumably reflected a change in lick "efficiency". Perhaps, due to postural adjustments, licking resulted in more efficient water intake.

EXPERIMENT 2

Under schedules of response-independent shock delivery, it was possible for the animals

to receive shock while they were licking. With response-dependent shock, on the other hand, shocks were closely associated with lever pressing and could hardly have occurred while the animals were licking. In Experiment 2, two rats were studied under conditions in which response-independent shocks were never delivered while the animals were licking. Attenuation of licking under these circumstances would strongly suggest that differential effects of shock on schedule-induced polydipsia may be attributed to the contingency between shock and behavior.

Procedure

After 15 sessions under an FT 60-sec schedule of food delivery, one of two male albino rats (Rat 1) failed to develop polydipsia. Although Rat 2 displayed characteristic licking, Rat 1 seldom licked after ingesting a food pellet and consumed only 3 ml per session. Therefore, while Rat 2 was being exposed to concurrent food-and-shock schedules, Rat 1

was further reduced to 70% of initial free-feeding weight in an attempt to generate schedule-induced polydipsia (Falk, 1969; Freed and Hymowitz, 1972). After 10 sessions of FT 60-sec at 70% weight, stable polydipsia emerged in Rat 1.

Each animal was exposed to concurrent FT 60-sec food and variable-time 180-sec (VT 180-sec) shock schedules. The interval between shocks ranged from slightly greater than 0 to 360 sec. A delay contingency was imposed so that electric shocks could not be delivered while the animal was licking. If shock was scheduled while the rat was licking, the shock was postponed until 5 sec after licking terminated. Blocks of five successive sessions at each shock intensity (0.30 to 0.60 mA) alternated with blocks of three successive shock-free baseline sessions.

RESULTS

Figure 4 shows mean water intake for Rats 1 and 2 under baseline and shock conditions. For Rat 1, shocks of 0.30 and 0.40 mA led to

rapid attenuation of water intake. However, by Session 5 under each shock intensity, water intake showed considerable recovery. Rat 1 was less severely affected by 0.50-mA shock but showed a marked attenuation of water intake under 0.60-mA shock, with no signs of recovery.

Rat 2 showed a similar pattern of behavior. Shock intensities of 0.40 and 0.50 mA led to marked disruption of water intake, with little if any, recovery during exposure to 0.50-mA shock. When shock was removed, baseline intake levels returned.

Figure 5 shows cumulative records of licking for Rat 1 under five sessions of 0.30-mA shock intensity. Attenuation of licking during Session 1 was quite abrupt. After delivery of several shocks, the animal ceased licking, although it continued to consume the food pellets as soon as they were delivered. Sessions 2 and 3 revealed continued attenuation of licking with isolated, sporadic episodes of licking throughout the session. Finally, in Session 5, recovery of licking occurred.

Fig. 2. Mean lever presses for each animal during baseline (B) and shock conditions of Experiment 1. See caption to Figure 1 for further details.

Fig. 3. Representative cumulative records for E-1 of lever pressing and licking during (left, from top to bottom) Session 20 of acquisition and Session 3 of 0.25-, 0.30-, and 0.40-mA response-independent shock and (right, from top to bottom) Session 10 of baseline and Session 3 of 0.25-, 0.30-, and 0.40-mA response-dependent shock. Lever presses are indicated by downward movements of the event pen; licks, by vertical stepping movement of the response pen; pellets, by downward movement of the response pen; shocks, by the resetting to the bottom of the vertical scale of the response pen. The response pen also reset to the bottom of the paper after a maximum excursion of 550 responses.

Fig. 4. Mean water intake for Rats 1 and 2 during baseline (B) and shock conditions of Experiment 2. The initial B-point represents the mean for Sessions 21 to 25 of acquisition for Rat 1 and Sessions 11 to 15 of acquisition for Rat 2. Successive B-points represent the mean of three successive sessions. Shock points represent the mean of five successive sessions. Asterisks indicate conditions in which the animal was not studied.

GENERAL DISCUSSION

Whereas response-dependent shock had little consistent effect on licking (Experiment 1), response-independent shock of comparable intensity and frequency dramatically reduced licking (Experiments 1 and 2). The decrease in licking under response-independent shock was a function of the intensity of shock, each animal differing with respect to the minimum intensity required to attenuate licking. The attenuation of licking cannot be attributed to the delivery of shock while the animal was licking, because, in Experiment 2, the animals ceased licking, even though they were never shocked while licking.

Dunham (1971) reported that response-dependent electric shock of sufficient intensity to suppress lever pressing led to an increase in schedule-induced polydipsia. Dunham's findings may not be incompatible with the present

Fig. 5. Representative cumulative records for Rat 1 of licking during (from top to bottom) Sessions 1, 2, 3, 4, and 5 of 0.30-mA response-independent electric shock delivery. See caption of Figure 3 for further details of the manner of recording.

findings. If, during the course of lever-press suppression, there is a decrease in the frequency with which food pellets are delivered, polydipsia may be expected to increase. Within certain limits, polydipsia is directly related to the duration of the inter-pellet interval (Falk, 1966). In the present study, the reduction of lever pressing by response-dependent shock was never so great as to cause a significant increase in the inter-pellet interval. On the other hand, Hymowitz (1973) reported that the inter-pellet interval on a fixed-ratio food schedule

increased substantially when electric shock was made dependent upon lever pressing, and the increase in the inter-pellet interval was accompanied by marked increases in polydipsia.

The question remains, why do animals cease licking under conditions of response-independent shock delivery? The answer is made more difficult because a satisfactory explanation of why animals develop polydipsia in the first place is not yet available. Several researchers (Denny and Ratner, 1970; Falk, 1971; Richards and Rilling, 1972) consider schedule-induced polydipsia to be a displacement activity, perhaps related to the aversiveness of intermittent feeding schedules. One might, with Segal and Oden (1969), reason that the addition of response-independent shock would add to the aversiveness of the feeding schedule, and hence lead to an increase in polydipsia. Support for this prediction was not provided by the present studies.

It is possible that the stimulus context necessary for the development of displacement activities such as schedule-induced polydipsia may be highly restricted. Accordingly, response-independent shock might have increased the aversiveness of the schedule and also altered the stimulus context necessary for polydipsia. Although further research is required, it is interesting to speculate that shock may have different effects on the total stimulus context, depending on the manner in which it is delivered.

REFERENCES

- Denny, M. R. and Ratner, S. C. *Comparative psychology*, Homewood: The Dorsey Press, 1970. Pp. 478-479.
- Dunham, P. J. Punishment: Method and theory. *Psychological Review*, 1971, **78**, 58-70.
- Falk, J. L. Production of polydipsia in normal rats by an intermittent food schedule. *Science*, 1961, **133**, 195-196.
- Falk, J. L. Schedule-induced polydipsia as a function of fixed-interval length. *Journal of the Experimental Analysis of Behavior*, 1966, **9**, 37-39.
- Falk, J. L. Schedule-induced polydipsia: type, size and spacing of meals. *Journal of the Experimental Analysis of Behavior*, 1967, **10**, 199-206.
- Falk, J. L. Conditions producing psychogenic polydipsia in animals. *Annals of the New York Academy of Sciences*, 1969, **157**, 569-588.
- Falk, J. L. The nature and determinants of adjunctive behavior. *Physiology and Behavior*, 1971, **6**, 577-588.
- Flory, R. K. The control of schedule-induced polydipsia: frequency and magnitude of reinforcement. *Learning and Motivation*, 1971, **2**, 215-227.
- Freed, E. X. The effects of conflict on schedule-induced consumption of water and alcohol. *Psychological Reports*, 1971, **29**, 115-118. (a)
- Freed, E. X. Schedule-induced polydipsia with nutritive and non-nutritive reinforcers. *Psychonomic Science*, 1971, **23**, 367-368. (b)
- Freed, E. X. and Hymowitz, N. Effects of schedule, percent body weight, and magnitude of reinforcer on acquisition of schedule-induced polydipsia. *Psychological Reports*, 1972, **31**, 95-101.
- Hymowitz, N. Effects of response-dependent and independent electric shock on schedule-induced water intake. *The Psychological Record*, 1973, **23**, 487-497.
- Richards, R. W. and Rilling, M. Aversive aspects of a fixed-interval schedule of food reinforcement. *Journal of the Experimental Analysis of Behavior*, 1972, **17**, 405-411.
- Segal, E. F. and Oden, D. L. Effects of drinkometer current and of foot shock on psychogenic polydipsia. *Psychonomic Science*, 1969, **14**, 13-15.

Received 20 June 1973.

(Final Acceptance 1 March 1974.)