Bulletin of the Psychonomic Society
1979, Vol. 14 (6), 460-462

A within-subjects study of variations in food pellet sucrose concentrations and steady state schedule-induced polydipsia

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Two food-deprived female albino rats received 16% sucrose pellets under a fixed-time (FT) 60-sec food-reinforcement schedule, with water freely available in the test chamber. After water intake stabilized for each animal, subjects received either 6% or 32% sucrose pellets under the same FT 60-sec reinforcement schedule. This phase was followed by a replication of the initial 16% sucrose pellet condition for each animal. Water intake was found to decrease for each animal following an initial shift from 16% sucrose pellets to 0% or 32% sucrose pellets, but not following shifts from 0% or 32% sucrose pellets to 16% sucrose pellets. Adjunctive behaviors and shift-related elation-suppression effects were compared and discussed.

Food-deprived rats exposed to intermittent schedules of food reinforcement ingest varying amounts of freely available water in the absence of experimenter-programmed contingencies between drinking and the delivery of food (Fairbank & Schaeffer, 1978; Schaeffer, 1977). As previously noted by Christian, Schaeffer, and King (1977), most research on schedule-induced drinking behavior of rats exposed to intermittent food reinforcement schedules has focused upon those subjects that, relative to individual baseline levels of consumption, quaff voluminous amounts of water. Because this phenomenon has not been shown to be a direct behavioral product of specific reinforcement contingencies, it is typically referred to as schedule-induced polydipsia (SIP).

Although the precise experimental parameters that are both necessary and sufficient for the development and maintenance of SIP have yet to be identified, quantitative and qualitative variations in environmental variables necessary for the development of SIP, such as degree of food deprivation (Falk, 1969; Keehn, 1979), type of fluid proferred (Ten Eyck & Schaeffer, 1969), and schedule of reinforcement employed (Falk, 1966; Schaeffer & Diehl, 1966), have been observed to dramatically affect total amounts drunk. Recently, a number of investigations into the determinants of SIP have focused upon the relationship between qualitative properties of dry-food reinforcers, pellet sugar in particular, and SIP (Christian, Reister, & Schaeffer, 1973; Christian & Schaeffer, 1973; Colotla & Keehn, 1975; Hart & Schaeffer, 1978; McCoy, Christian, & Tolan, 1979; Schaeffer & Brush, 1978; Schaeffer & Fairbank, Note 1). Studies employing between-group experimental designs, in which independent groups of subjects differ in the sucrose content of dry food pellets to which they are exposed, have reported modest, inverse ordinal, long-term steady state relationships between pellet sucrose content and SIP (Christian et al., 1973; Christian & Schaeffer, 1973; Fairbank & Schaeffer, 1978; Schaeffer & Brush, 1978). As a direct procedural contrast with the between-groups experimental design, other investigators have employed within-sessions probe (Colotla & Keehn, 1975; Falk, 1967) procedures to examine the immediate effects upon SIP of manipulating pellet sugar composition in the same subjects. In the within-session probe design, subjects are typically exposed to a baseline formula pellet for several sessions of intermittent food reinforcement, followed by one or more sessions in which pellets of varied sugar concentration are substituted within sessions for a percentage of the baseline formula reinforcements. In the between-sessions probe procedure, subjects are exposed to one type of dry food pellet for an entire session or several sessions, and then they are shifted to a pellet with a different concentration of sugar for an entire session. Studies employing the within-sessions probe design and the between-sessions probe procedures have reported dramatically large, immediate, pellet composition-related effects upon SIP that persist throughout the brief period the probe procedure is in effect and are reversible when subjects are returned to the baseline state. As has been the case with the between-groups studies, the probe procedures studies have shown an inverse ordinal relation between sugar content of the pellet and SIP, but the magnitude of the effect has been much greater in the latter than in the former.

Because the long-term steady state effects of manipulating pellet sugar content within subjects are unknown, the present study was undertaken. First, steady state baseline levels of water intake on a fixed-time (FT) 1-min schedule with Noyes dry food pellets containing 16% sucrose were compared with steady state water intake following shifts to Noyes 32% sucrose pellets or Noyes sugarless (0% sucrose) pellets. Second,

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0090-5054/79/120460-03$00.55/0

steady state water intakes associated with reinstatement of 16% Noyes sucrose pellets were compared with those in each of the preceding conditions.

METHOD

Subjects

The subjects were two female albino rats, approximately 130 days old. They had previously served in an experiment involving a FT 1-min schedule of reinforcement with Noyes 45-mg 16% sucrose dry food pellets. In a FT 1-min schedule, reinforcement is dispensed each 60 sec, independently of the behavior in which the subject is engaged. Neither subject had any previous experimental history with any food pellet other than the Noyes 45-mg 16% sucrose pellet.

The subjects were housed individually in Wahmann LC 175-C75 cages under conditions of constant illumination and relatively constant temperature and humidity. They were reduced to 85% of their free-feeding weights and maintained at that level throughout the experiment. At all times, water was freely available to subjects in the home cage and experimental chamber.

Apparatus

Two Lehigh Valley Electronics (LVE Model 132-02) standard experimental small animal chambers were employed throughout the study. Both chambers were modified slightly by removing the right lever to permit insertion of a standard Wahmann stainless steel drinking tube. Delivery of pellets was automatically accomplished by a Data General Nova 2 computer and standard electromechanical circuitry. Water intakes were determined by weighing the water bottle before and after each experimental session and converting these values to milliliters.

Procedure

The present study consisted of three experimental phases: (1) FT 1-min schedule of dry food with 45-mg Noyes 16% sucrose pellets, (2) FT 1-min schedule of dry food reinforcement with shift to 45-mg Noyes 32% sucrose or 45-mg Noyes sugarless (0% sucrose) pellets, and (3) FT 1-min schedule of dry food reinforcement with reinstatement of 45-mg Noyes 16% sucrose pellets. Daily experimental sessions were 100 min in duration, the length of time required to dispense 100 pellets to each animal on the FT 1-min schedule of reinforcement.

In the first phase, each animal received 100 45-mg Noyes 16% sucrose pellets on a FT 1-min schedule of pellet delivery. Subjects remained in this initial experimental phase until volume of water consumed stabilized for each animal. Steady state stability criteria for this and subsequent phases required that the difference between the total water intakes for the last three and the previous three experimental sessions be less than 20% of the total intake of the last six sessions for each animal.

In Experimental Phase 2, subjects were randomly assigned to shift conditions. Subject 1 received 100 45-mg Noyes 32% sucrose pellets, and Subject 2 received 100 45-mg Noyes sugarless (0% sucrose) pellets, on a FT 1-min schedule of reinforcement. In Experimental Phase 3 the FT 1-min schedule of dry food reinforcement with 16% sucrose pellets was reinstated for each animal.

RESULTS

Water intakes for each subject, across all phases of the study, are presented in Figure 1. Visual inspection of the data indicated a steady increase in water consumption for each animal over the first six sessions, reaching asymptote by the eighth session, with little difference between animals in steady state drinking evident. Statistical comparison of steady state water intakes over the last six sessions of Phase 1 corroborated this observation by revealing a statistically nonsignificant difference [$t(5) = .41$, $p > .05$] in baseline steady state water intakes when both subjects were receiving 16% sucrose pellets.

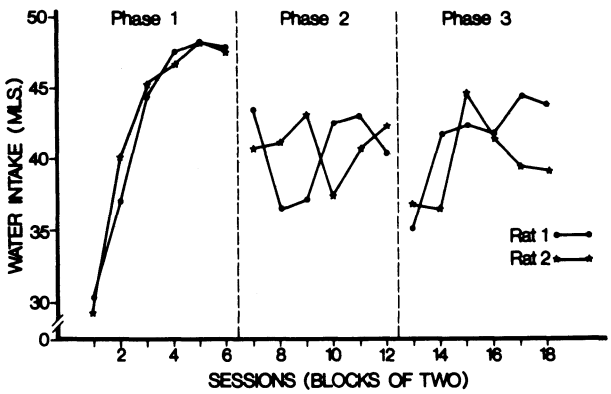

Figure 1. Experimental session water intakes averaged across blocks of 2 days for Subjects 1 and 2.

In Experimental Phase 2, Subject 1 was shifted from 16% sucrose pellets to 32% sucrose pellets, and Subject 2 was shifted from 16% sucrose pellets to sugarless (0% sucrose) pellets. Visual inspection of Figure 1 indicates an approximate 8-ml decrease in steady state water intake for each animal during Phase 2, relative to Phase 1 preshift intake volumes. Application of a one-way analysis of variance to the steady state water-intake data of each subject yielded a significant effect for phases [Subject 1: $F(1,5) = 8.6$, $p < .05$; Subject 2: $F(1,5) = 39.5$, $p < .05$], indicating that steady state water intakes for each animal were significantly lowered by shifts from the 16% sucrose pellets to the 32% sucrose and sugarless pellets. As is evident from the data shown and as was confirmed by statistical analysis, the subjects did not differ in amount drunk in Phase 2 [$t(5) = .92$, $p > .05$].

In Experimental Phase 3 each subject was exposed to a FT 1-min dry food reinforcement schedule with 16% sucrose pellets. Examination of Figure 1 indicates that the steady state SIP in Experimental Phase 3 was at essentially the same level as steady state water intake in Experimental Phase 2 and that it continued at approximately 8 ml less than the steady state SIP obtained in Experimental Phase 1. One-way analyses of variance comparing steady state intake values of Experimental Phases 1, 2, and 3 corroborated what is evident in Figure 1. Water intakes differed significantly between Experimental Phases 1 and 3 [Subject 1: $F(1,5) = 14.8$, $p < .05$; Subject 2: $F(1,5) = 40.9$, $p < .05$] but not between Phases 2 and 3 [Subject 1: $F(1,5) = .4$, $p > .05$; Subject 2: $F(1,5) = .01$, $p > .05$]. As was the case in Phases 1 and 2, no significant difference between subjects in amount drunk in Phase 3 was found [$t(5) = 2.5$, $p > .05$].

DISCUSSION

In the current study, within-subjects shifts to both sugarless pellets and pellets with a relatively higher concentration of sugar, by weight, produced significant steady state decrements in SIP from baseline levels. Although quantitatively less dramatic than the large decrements in water intake reported with between-sessions probe (Colotla & Keehn, 1975) and within-sessions probe (McCoy et al., 1979) designs, the present results give directional corroboration to their findings.

The present data are inconsistent with the data from studies employing within-subjects between-sessions shift designs (Marx, 1969; Weinstein, 1970) and using instrumental leverpressing reinforced by sugar. Animals shifted from sugarless pellets to relatively high-concentration sucrose pellets have shown an increase in rate of instrumental responding (Marx, 1969), and animals shifted from a high-concentration sucrose reinforcer to a lower concentration sucrose reinforcer have shown a decrease in instrumental response rate (Weinstein, 1970). Although the magnitude and reliability of shift-associated qualitatively induced effects are controversial, postshift elation and depression effects produced by qualitative variation in reinforcers are found often enough with instrumental responses to suggest they may be real effects. In the present study, the depressive effect in drinking associated with both upward and downward sucrose concentration shifts (cf. Phases 1 and 2 for Subjects 1 and 2) and the absence of any shift effect when the subjects were returned to baseline condition in Phase 3 are potentially explicable by analyzing the relationship between drinking in the present study and instrumental responding that can be directly under the control of the reinforcing consequences of pellet delivery.

Schedule-induced drinking is considered an adjunctive, rather than an instrumental, response since ordinarily it does not appear to be maintained by specific, experimenter-programmed reinforcement contingencies (Falk, 1971, 1977). Since the present study employed a FT schedule, no specific instrumental response was programmed to produce the food pellets. In Phase 2 of the current study, Subject 2 showed a decrement in drinking following a downshift in pellet sucrose concentration, whereas Subject 1, following an upward shift in pellet sucrose concentration, showed a decrease in drinking equal in magnitude to the depression effect of Subject 2. The absence of any shifts in drinking in Phase 3 and the lack of total predictability of directionality of drinking behavior in Phase 2 suggest that adjunctive behaviors (i.e., those not under the direct control of a reinforcer) may be less influenced by qualitative properties of consumable reinforcers than by change per se. What is clearly needed if the effects of shifts in pellet sucrose concentrations on instrumental and adjunctive behaviors are to be determined, is a study employing pellet-reinforced instrumental responding and providing opportunities for adjunctive behaviors that uses more subjects and a within-sessions between-groups experimental design that will permit analysis of the differential effects of qualitatively disparate reinforcers on instrumental and adjunctive behaviors. Research on this problem is currently underway in our laboratory.

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(Received for publication October 22, 1979.)