

Schedule-induced polydipsia as a function of NaCl composition of the food reinforcer

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Four groups of four rats each received Noyes food pellets containing 0%, 7.5%, 10%, or 15% NaCl on a fixed-time (FT) 60-sec food reinforcement schedule. Relative to fluid intake levels in the baseline sessions that preceded and followed the FT schedule, water consumption in the FT 60-sec condition increased dramatically. Water intakes for the three NaCl groups differed significantly from the no-NaCl group only in the FT condition, but did not differ among NaCl groups under any condition. It is concluded that schedule-induced polydipsia is not explicable by appeals to underlying physiologically mediated response mechanisms.

Food-deprived rats that are subjected to dry-food intermittent reinforcement schedules frequently consume large amounts of fluids (Falk, 1961, 1964). This phenomenon, schedule-induced polydipsia (SIP), occurs even though food-deprived rats typically decrease, rather than increase, their fluid intakes (Strominger, 1946). Furthermore, the SIP drinking response is not programmed by the experimenter as a specific instrumental response which produces food, nor does the rat respond as if drinking were an adventitiously reinforced or superstitiously maintained instrumental response requirement for food delivery (Clark, 1962; Falk, 1964; Schaeffer & Salzberg, 1967).

Several studies suggest that the level of SIP exhibited by rats exposed to dry-food reinforcement schedules may be related to the sugar composition of the food pellet. Falk (1967) observed that the substitution of either 92.4% sucrose or 91.3% dextrose Noyes pellets for standard formula Noyes pellets produced a rapid reduction in drinking (relative to the large amounts of fluid the rats previously had consumed when they received standard Noyes pellets) and reasoned that sweeteners in food pellets might be inimical to the development and maintenance of SIP. Subsequently, however, Burks, Hitzing, and Schaeffer (1967), used a fixed-time (FT) schedule in which rats received a pellet each 40 sec, independently of their ongoing behavior, and obtained SIP in rats that had received standard formula Noyes pellets, to which 4% sucrose had been added, from the onset of the experiment. Years later, Christian and Schaeffer (1973a) discovered that the standard formula Noyes 45-mg food pellets, which Burks et al. (1967) had assumed were sugarless, actually contained 7.5% glucose by weight. Communication with executives at the Noyes Pellet Company indicated that

the additive glucose was being used as an ingredient neither for its caloric value nor for palatability factors, but as a binding agent to reduce the possibility of pellet shattering in mechanical pellet dispensers. Thus, variations in Noyes pellet sugar composition reported by experimenters prior to 1973 typically consisted of the standard Noyes pellet Formula A with 7.5% glucose binder, plus the reported variations in sugar content (Christian & Schaeffer, 1973a).

In a between-groups experiment that used standard Formula A Noyes pellets to which no glucose had been added as a binding agent, but which did contain 0%, 4%, 16%, or 32% sucrose, Christian and Schaeffer (1973b) found that four groups of rats exposed to a FT 60-sec schedule drank water in inverse proportion to the sucrose composition of the pellets. Subsequently, the inverse relationship between pellet sucrose concentration and group water intakes on FT schedules they reported was replicated in a between-groups experiment by Christian, Riester, and Schaeffer (1973) in which glucose pellet concentrations of 0%, 4%, 16%, and 32% were used. Using a within-groups experimental design, rather than the between-groups designs used by Christian and Schaeffer (1973b) and Christian et al. (1973), Colotla and Keehn (1975) gave rats working on a fixed interval (FI) 60-sec schedule for food pellets containing either 0% or 7.5% glucose, or 4% or 32% sucrose, opportunities to drink water, saccharin, alcohol, or nothing, concurrently with the food schedule. In contradistinction to the results obtained by Christian and Schaeffer (1973a), Colotla and Keehn (1975) found that 7.5% glucose pellets produced higher levels of drinking than did sugarless pellets. With that single exception, Colotla and Keehn's results did, however, replicate Christian and Schaeffer's findings that amount of fluid drunk was inversely related to sucrose composition of the pellet. Christian (1975a, 1975b) and Christian and Schaeffer (1975), however, have reported (1) that rats receiving 0% sugar pellets emitted more licks during lick-contingent fixed-ratio (FR 60, FR 90, FR 150) food reinforcement

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schedules than did rats receiving either 7.5% sucrose or 7.5% glucose pellets, (2) that this same relationship between pellet composition and amount of water consumed was obtained in rats working on FI schedules in which leverpressing served as the instrumental response and (3) that rats receiving sugarless pellets drank more and emitted higher lever response rates than rats receiving either 7.5% sucrose or 7.5% glucose pellets. Thus, although sugar composition of the pellet does appear to have some influence upon amount drunk in both time- and response-dependent food reinforcement schedules, the precise relationship between pellet sugar composition and SIP is in need of further examination and clarification.

Insofar as we have been able to determine, variations in sugar type (sucrose vs. glucose) and percent sugar content apparently are the only food-composition-related independent variables that have been manipulated in SIP studies that have used Noyes food pellets as food reinforcers. As suggested above, qualitative and quantitative variations in the sugar composition of Noyes pellets at best have produced modest and somewhat unreliable effects upon collateral fluid intakes. Salt intake, whether accomplished by vein or stomach loading, and water intake are reported to be intimately and dramatically related in a positive fashion (Adolph, 1964). Consequently, the present study was undertaken to determine what effects various concentrations of NaCl in Noyes food pellets might have upon the development and maintenance of SIP.

METHOD

Subjects

Sixteen experimentally naive male albino rats, approximately 90 days old at the start of the experiment, were used. They were maintained throughout the experiment at 85% of their free-feeding weights by supplementary feeding of Purina Lab Chow given after each daily session. Water was freely available in the home cages and test chambers throughout the entire experiment.

Apparatus

Four standard Lehigh Valley Electronics Model 132-02 two-bar test chambers, modified by removal of the right bar to permit insertion of a metal drink spout, were used. The drink spout was located 7 cm to the right of the food cup and 3.5 cm above the floor. Consistent placement of the drink spout and water bottle was insured by a plastic holding device mounted to the exterior of the test cubicle. Pellet deliveries were programmed automatically by standard relay circuitry. Licks and pellet deliveries were sensed and recorded on Gerbrands cumulative recorders and Esterline-Angus digital operations recorders. Daily session water intakes were calculated by converting to milliliters the weight difference of the water bottle, determined by weighings before and after each session.

Procedure

The 16 rats were randomly divided into four groups of 4 animals each. During all phases of the experiment, each group received the same basic Noyes 45-mg food pellets, (Formula A, without the 7.5% glucose binder) to which either 0%, 7.5%, 10%, or 15% NaCl had been added. Throughout the experiment, each of the four test chambers vended only one of the four types

of NaCl pellets. Thus, all four members of each group were tested in the same chamber throughout the entire experiment.

The experiment consisted of three phases: (1) baseline, (2) FT 60-sec, and (3) reinstatement of baseline. During each of the baseline phases, 60 of the appropriate formula food pellets were first placed in the food cup, then the appropriate animal was placed in the chamber. Each rat remained in its experimental chamber for 60 min, during which the empty pellet dispenser was operated once every 60 sec. During the FT 60-sec phase, the food cup was empty when the animal was placed in the chamber, and the appropriate food pellet was dispensed to each animal every 60 sec for 60 min, irrespective of the animal's behavior. Water was freely available in the test chamber and in the home cage during all phases of the experiment.

Each experiment phase was continued until chamber water intakes stabilized. The stability criterion employed (Schoenfeld, Cumming, & Hearst, 1956) required the difference in intake between the mean of the last three daily sessions and the mean of the preceding three daily sessions to be less than 10% of the overall mean for all six sessions. The criterion was met by all 16 animals before a new experimental phase was introduced.

RESULTS AND DISCUSSION

The mean water intakes for the four pellet concentration groups across the three experimental conditions are presented in Figure 1. Relative to the initial baseline, the instatement of the FT schedule produced a dramatic increase in mean water intakes for all groups. Only two animals in the 15% NaCl group, and one animal each in the 0% and 7.5% NaCl groups, failed to more than double their initial baseline water intakes in the FT condition. A twofold or more increase in volume of fluid drunk in the experimental phase, relative to amount drunk in the initial baseline phase, defines SIP in our laboratory (Christian, Schaeffer, & King, 1977). Mean group water intake values in the return-to-baseline phase equalled those values obtained in the initial baseline. A repeated-measures analysis of variance that used the water intake data from the last six daily sessions of each baseline phase confirmed the visual impression of a nonsignificant difference between the baselines and

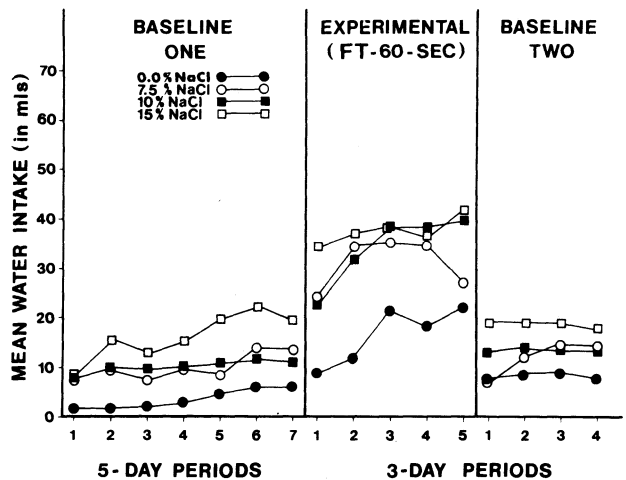


Figure 1. Group mean milliliters sessional water intake as a function of pellet NaCl content in all three phases of the experiment.

demonstrated, statistically, the reversibility of SIP.

An additional repeated-measures analysis of variance, performed on the water intake data obtained from all groups during the last 6 days of each of the three phases of the experiment, revealed statistically significant main effect differences only for pellet NaCl concentration [$F(3,273) = 5.54$, $p < .05$], and experimental phases [$F(2,24) = 90.57$, $p < .05$]. As suggested by the nonsignificant difference between baselines reported above, the significant difference between experimental phases was due to the substantive increase in drinking observed in the FT phase of the experiment. Analysis of the relationship between pellet NaCl concentration and water intake magnitude, during the FT phase, as evaluated by Duncan's new multiple range test (Kirk, 1968), revealed that the mean water intake for the group receiving 0% NaCl pellets was significantly less than the mean water intakes of the other three groups ($p < .05$). The mean water intakes for the three groups receiving NaCl pellets, though positively correlated with NaCl concentration, did not differ significantly from each other. Thus, the present results do not provide specific support for the suggestion that Noyes standard Formula A pellets without the 7.5% glucose binder produce higher water intake levels than pellets that contain more preferable constituents (Christian & Schaeffer, 1973b, 1975). These results do, however, support the suggestion by Christian and Schaeffer (1973b), Colotla and Keehn (1975), and Falk (1967) that pellet composition influences total amount drunk, but the specific qualitative and quantitative aspects of this proposed relation have yet to be firmly established.

The proportion of food pellets followed by drinking is purported to be the single most important factor for the production of SIP in normal rats (Christian et al., 1977; Shumake, 1968) and in desalivate rats (Schaeffer, 1977) exposed to intermittent food reinforcement schedules. Shumake (1968) showed that rats typically emit bursts of licking in the 90- to 225-lick range, both under nonrestricted food regimens and when food deprived, and that increased fluid intakes associated with intermittent food scheduling are the product of an increase in the probability of a food pellet being followed by a burst of licking in the 90- to 225-lick range, rather than a function of large increases in lickburst length. Schaeffer (1977) has found essentially the same relation in desalivate rats. Further, Colotla and Keehn (1975) have found that pellet sugar composition differentially affects the proportion of pellets that are followed by drinking, but has no substantive effect upon the length of the lickbursts that follow sugarless, sucrose (4% or 32%) or glucose (7.5%) pellets. The preceding results intimate that lickburst length might profitably be examined in the present study.

Table 1 summarizes the mean frequency of specific categorized postpellet lickburst distributions obtained, during the FT phase of the present experiment, from

Table 1
Mean Percent of Licks Occurring in Each Lickburst Category During the Last 6 Days of the FT 60-sec Phase as a Function of Percent Pellet NaCl Content

Lickburst Length Category	Percent Pellet NaCl Content			
	0	7.5	10	15
0	33	15	2	5
1- 89	30	55	32	39
90-179	36	29	61	54
180-269	1	1	5	2

each of the four groups. These data were obtained by recording for each rat the frequency with which each lickburst category occurred during the last six daily sessions of the FT phase, then converting these totals to mean daily percent of responses obtained in each lickburst length category, for each group. It is readily apparent from the averages presented in Table 1 that (1) a relationship existed between *presence* or *absence* of NaCl and the likelihood that a pellet would be followed by a lickburst, (2) no significant relationship existed between the percent of NaCl contained in the pellet and the likelihood that a pellet would be followed by a lickburst, and (3) no less than 65% of all postpellet lickburst lengths fell within the range of 1 to 179 licks, and for the NaCl pellet groups, more than 80% of all lickburst lengths fell within that range. These findings add support to previous observations that SIP is more attributable to increased frequency of drinking than to changes in lickburst length.

Given the results presented above, two points seem worthy of attention. First, since the amount of fluid consumed was not a linear function of the salt content of the food pellets, further support is lent to the assertion that SIP is not a basic regulatory response of the organism to immediate physiological demands (Schaeffer, 1977). Second, the effects of food pellet composition upon amount of fluid consumed, when compared to either (1) the effects of different reinforcement schedules upon amount of fluid consumed, or (2) the effects that basic fluid preferences have upon amount of collateral fluid ingested under reinforcement schedules that reliably produce SIP (cf. Roll, Schaeffer, & Smith, 1969; Shumake, 1968; TenEyck & Schaeffer, 1969) are minimal. Thus, the phenomenon may be exemplary of the normal eat-drink bias of the rat which is altered in frequency by constraints imposed by the experimenter on the number of pellets the rat is permitted to treat as a meal in free-access, as opposed to limited-access, conditions.

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