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The Effects of a Controlled Eating and Drinking History on the Development of Schedule-Induced Polydipsia

Norman Hymowitz

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THE EFFECTS OF A CONTROLLED
EATING AND DRINKING HISTORY ON THE
DEVELOPMENT OF SCHEDULE-INDUCED POLYDIPSIA

by

Norman Hymowitz

A Thesis
Submitted to the
Faculty of the School of Graduate
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of the
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INTRODUCTION

Schedule-induced polydipsia was introduced into the psychological literature by Falk (1961a). With water freely available in the test chamber, rats pressing a bar on a continuous reinforcement schedule (CRF) with dry food pellets as reinforcement and then switched to an intermittent schedule of reinforcement developed a characteristic pattern of alternating between pressing the bar, ingesting the food pellet, drinking water, pressing the bar, etc. The consistency of such alternations throughout the test session resulted in water consumption which was three to four times as much as rats' normal 24 hour water intake. Excessive fluid consumption and the typical alternation between food and fluid intake also occurs with alcohol as the available fluid (Lester, 1961; Freed, 1967). The excessive fluid intake, as much as 100 ml of water in a three hour session, intrigued researchers since the rats had free access to water in their home cages and were not water deprived.

As noted by Falk, (1961b) previous illustrations of polydipsia in the laboratory have been classified as either metabolic polydipsia or regulatory polydipsia. The first case involves conditions where the organism experiences excessive fluid loss. In the latter case, the abnormality in water intake originates from either central nervous system defects which stimulate central thirst centers or from shifts in body fluid electrolyte balance such as occurs with sodium depletion. Since no physiological defect has been demon-

strated in schedule-induced polydipsia (SIP), Falk (1961a) used the term "psychogenic" to describe the phenomenon. Lester (1961) referred to the consistent pattern of alternating between the food and water as "compulsive" in nature. Despite the label that may be applied to SIP, psychologists were particularly interested in this behavior as an example of the strong effects which environmental contingencies may have on normally physiologically regulated behavior.

Effects of Schedules of Reinforcement on SIP

Hitzing (1968) noted that psychologists have been traditionally concerned with the effects of schedules of reinforcement on the development, maintenance, and extinction of SIP. Levels of food deprivation, availability of fluid, and the past history of the organism have been held constant, while reinforcement schedules were systematically manipulated. It has been shown (Falk, 1961; Lester, 1961; Clark, 1962) that SIP does not occur when the food pellets are delivered on CRF. However, with an inter-pellet interval of at least 30 sec, SIP develops rapidly (Falk, 1966a). Schedule-induced polydipsia has been generated with variable interval (VI) schedules of reinforcement (Falk, 1961a; Lester, 1961; Clark, 1962), fixed interval (FI) schedules (Stein, 1964; Falk, 1966a; Freed, 1967), and also with differential reinforcement of low rate (DRL) schedules (Segal and Deadwyler, 1965). The bar-press is not a necessary condition for the development of SIP since SIP occurs when the pellets are delivered according to a free fixed interval

(FFI) schedule of food reinforcement (Segal, Oden, and Deadwyler, 1965; Schaeffer, Diehl, and Salzberg, 1966; Burks, Hitzing, and Schaeffer, 1967).

Response dependent schedules of reinforcement, in which the subject (S) is required to emit a specified number of responses before the food pellets are made available, also generate SIP (Schaeffer and Diehl, 1966; Falk, 1966b), but the water intake is not as great as intake produced during time dependent schedules. Fixed ratio (FR) schedules are conducive to the development of SIP but only if the response requirement is at least 80 responses. Lower ratios, as noted by Schaeffer and Diehl (1966) and Falk (1966b), do not support SIP. Long post-reinforcement pauses, generated by the high ratio requirement, may be related to the above mentioned notion that post-pellet intervals of 30 sec or more are necessary for the development and maintenance of SIP. More research is required in this area to gain fuller understanding of the interaction between responses and pauses.

Effects of Dry Food Pellets on SIP

Malott and Cumming (1965) failed to produce SIP when rats were placed in a Sidman avoidance situation. In Sidman avoidance tasks, rats press a lever which in turn postpones the delivery of an electric grid shock for a specified length of time. The rats neither alternated between bar-pressing and drinking nor did they consume excessive quantities of water. It has also been shown (Segal and

Deadwyler, 1965; Hymowitz and Freed, 1968) that SIP ceases when the pellets are no longer dispensed (extinction).

Since the ingestion of the food pellet appears to be a necessary condition for SIP to occur, it is necessary to food deprive the rats so that they will ingest the food pellets in the test chamber. Satiated subjects (Ss) neither bar-press nor consume excessive amounts of water. With alcohol as the available fluid, however, rats continue to drink during the extinction sessions (Hymowitz and Freed, 1968). It appears that the caloric value of the alcohol is an important factor in the continued alcohol consumption. When the rats were food satiated, the alcohol consumption ceased.

Thirst due to the ingestion of a dry food pellet was considered a necessary condition for the development of SIP. Stein (1964) showed that when liquid reinforcements, such as milk, were substituted for dry food pellets, excessive water consumption ceased. Stricker and Adair (1966) noted that SIP did not appear with food deprived rats given vegetable oil as reinforcement on a VI schedule. Falk (1967), however, reported the production of SIP when liquid standard monkey diet was used as reinforcement. Falk (1964; 1967) also showed that SIP did not develop when either sucrose pellets or dextrose pellets were used as reinforcement. Falk concluded that dry food pellets were neither necessary nor sufficient for the development of SIP. The inability to generate SIP with dextrose pellets may be related to the fact that dextrose pellets are

carbohydrates, while the usual dry food pellets employed in SIP studies consist chiefly of protein. As noted by Hoar (1967), excess water is released during the metabolism of carbohydrates, while protein metabolism requires much water, and there is no water released in the process. It should be realized, however, that the rapid development of SIP almost precludes complete dependence on metabolic feedback.

A recent study by Burks, Hitzing, and Schaeffer (1967) demonstrated SIP with sucrose pellets as reinforcement. Their procedure differed from Falk's (1964) in that the former researchers introduced the sucrose pellets during the initial sessions in the test chamber while Falk first obtained SIP with dry Noyes pellets and then switched to the sucrose pellets. A previous study (Premack and Hillix, 1963) showed that mid-experimental changes in sucrose concentration produces dramatic and persistent shifts in consummatory responding. The time at which the sucrose pellets are introduced may account for the differences between the above mentioned studies.

Effects of the Arrangement of the Test Chamber on SIP

Lester (1961) noted that the fluid, whether alcohol or water, must be present throughout the shaping and training sessions in order for SIP to develop. Rats trained to bar-press without having water freely available did not develop SIP when the water spout was introduced after several sessions on an intermittent schedule.

Clark (1964) reported that the proximity of the water spout to the lever, which he claimed influences the initial frequency of drinking following reinforcement, is an important variable in determining whether SIP will or will not develop. If the distance between the lever and drinking spout was more than nine inches, Clark noted that SIP did not occur.

Adventitious Behavior as an Explanation for SIP

Williams and Teitlebaum (1956) produced excessive water consumption in rats by programming contingencies in such a manner that licks at a drinking spout were followed by the avoidance of an electric grid shock. In a more recent study by Koh and Teitlebaum (1961) excessive drinking was established by programming the availability of food pellets contingent upon water consumption. Contingent drinking served as a basis for positing adventitious reinforcement as an explanation of SIP. Teitlebaum (1961), commenting on the nonhomeostatic nature of SIP, claimed that the explanation was most likely due to a fortuitous or adventitious relationship which developed between the presentation or availability of food pellets and licks on the drinking spout. Clark (1962) noted that in the process of developing intermittent schedules of reinforcement, termination of bursts of licks on the drinking spout often preceded the delivery of the pellet. As the inter-pellet intervals were gradually lengthened, longer and longer bursts of licks were adventitiously reinforced so that there was a high probability that termination of prolonged bursts of licks were

immediately followed by the availability of the food pellet. Clark stated that initial contacts with the water spout may have resulted from the influence of dry mouth and throat, however, as the intermittent schedule of reinforcement was manifested, drinking came under the control of adventitious contingencies.

Segal (1965) suggested that drinking was one of a chain of responses which terminated in the delivery of the food pellet. Animals consume the pellet, drink water, "do something else," press the bar, and once more consume the food pellet. Segal and Holloway (1963) claimed that excessive water consumption and "doing something else" served as mediating or timing responses. It should be recalled, however, that Malott and Cumming (1965) showed that water consumption was not used as a timing or mediating response in the Sidman avoidance situation.

Segal, Oden, and Deadwyler (1965) supported the adventitious reinforcement hypothesis with their research on extinction. Schedule-induced polydipsia ceases when the pellet dispenser is made inoperable. Segal et al. showed that Ss drank more water during extinction sessions when the click of the pellet dispenser was audible than when it could not be heard. The authors attributed this difference to the effects of conditioned reinforcement. The click acted as a reinforcer because of its previous association with food pellets. It should be noted that drinking during extinction was not excessive. Classical conditioning may also favor an explanation of SIP based on thirst. As in the case of Pavlov's dog salivating in response to a buzzer that had been repeatedly paired

with food powder, so too, a rat might drink when a click is presented that in the past had been repeatedly paired with sensations of dry mouth.

Evidence Against the Adventitious Reinforcement Hypothesis

According to Herrnstein (in Honig, 1966), adventitious behavior, whether it is a chain of events or a single event, precedes the reinforcing event. Recent studies (Stein, 1964; Falk, 1966b; Burks, Hitzing, and Schaeffer, 1967; Hitzing, 1968) demonstrated, by analysis of cumulative records of SIP during FI schedules of reinforcement, that drinking follows rather than precedes the delivery of the pellet. In a comparison between contingent and non-contingent licking, Hitzing (1968) defined contingent licking as that which precedes the delivery of the food pellet while non-contingent licking follows the delivery and consumption of the pellet. When the reinforcement schedule was changed from a lick-contingent FI to a FFI schedule of reinforcement, contingent pre-pellet drinking ceased while non-contingent post-pellet drinking was maintained.

Hitzing (1968) demonstrated that drinking was not under the control of adventitious reinforcement when food pellets were delivered on a FFI schedule. The apparatus was programmed so that each lick at the drinking spout postponed the delivery of food pellets a specified amount of time. All Ss, as well as yoked controls, displayed SIP despite the fact that drinking never immediately preceded the delivery of a food pellet.

Recent studies (Schaeffer, Diehl, and Salzberg, 1966) analyzed SIP in the light of Premack's (1965) response rate theory. The theory deals with the notion that low probability responses can be made more probable by making high probability responses contingent upon the low probability responses. Proponents of the adventitious reinforcement hypothesis claim that both responses, bar-pressing and drinking, are maintained by the same reinforcing event, the delivery of the food pellet. When the schedule is changed to a FFI schedule of reinforcement from a bar-press FI schedule, bar-pressing either ceases or is reduced considerably, while the number of licks does not decrease. Licking, the "low probability response," was not made more probable by the fact that a high probability response, bar-pressing and consuming the pellets, was adventitiously contingent upon it.

Although empirical evidence mitigates against acceptance of adventitious reinforcement as the sole explanation of SIP, it should not be misconstrued that adventitious reinforcement cannot play a role in the development of SIP. Schaeffer and Salzberg (1967) discuss an "atypical" case where adventitious reinforcement may have maintained drinking behavior. The author noted that FFI schedules of reinforcement maintain substantial non-thirst behavior such as bar-presses when shifted from bar-press FI schedules. This fact suggests the possibility that some Ss drink because of an adventitious correlation between drinking and food delivery. On an FFI schedule, Schaeffer and Salzberg reported that one rat displayed a high rate of both bar-pressing and drinking after each pellet

was consumed. When the schedule was switched to a low response dependent schedule that was not reported to be conducive to the development of SIP, the "atypical" rat continued to drink after each pellet. As noted by Schaeffer et al., "...S behaved as though an adventitiously maintained drink to bar-press to eat response chain was in effect" (p. 107⁴).

Dry Mouth Theory of Thirst as an Explanation for SIP

The inter-pellet distribution of non-contingent drinking bursts as a post-pellet occurrence, led to a hypothesis or explanation of SIP based on dry mouth theories of thirst (Stein, 1964). Stein posited an interaction between sensations of dry mouth, supposedly produced by the dry food pellets, and the opportunity to drink during the inter-pellet interval. Stricker and Adair (1966) suggested that for food deprived rats, the "need to relieve the sensations of dry mouth" are ordinarily subsidiary to the hunger drive. However, during the course of responding on an intermittent schedule, the rat learns to utilize the post-pellet interval to relieve sensations of dry mouth. Falk (1966b) showed that rats develop SIP on FI schedules, cease drinking when switched to CRF, and resume drinking when the schedule of reinforcement is changed to either an FI, VI, or FR schedule of reinforcement.

As noted by Grossman (1967), dry mouth theories of thirst and water regulation, though logical from the common sense point of view, have not been supported by empirical evidence. To the contrary,

the evidence points toward electrolyte balance, osmoreceptors, and central mechanisms as determiners of water intake. Work by Wolf (1958) lends credence to interpretations of SIP based on thirst. Wolf suggested that a past history of pairing sensations of dry mouth with internal states of water deprivation may have conditioned dryness of mouth to serve as a discriminative stimulus for drinking. Stricker and Adair (1966) showed that internal factors may not be as crucial for SIP as they are for other types of polydipsia. Analysis of plasma and muscle samples indicated that SIP persists despite the dilution and overhydration of the body fluids.

The Meal Hypothesis as an Explanation for SIP

The thirst hypothesis alone cannot account for the excessive nature of the drinking response. Rats normally regulate their fluid intake according to their food intake (Bolles, 1961). The large amounts of water consumed following the consumption of a 45 mg Noyes pellet is difficult to account for solely on the basis of dry mouth. Falk (1967) showed that increasing the number of pellets per reinforcement presented to S without increasing the inter-pellet interval did not increase post-pellet fluid intake. Recent studies (Stein, 1964; Schaeffer and Diehl, 1966; Falk, 1967) indicate that the alternation between eating and drinking is related to the rat's normal pattern of drinking after consuming food. Schaeffer and Diehl (1966) operationally defined a "meal"

as any number of reinforcements followed by drinking. A 45 mg pellet of food may be considered a meal if the rat drinks after ingesting it. In the experimental situation, each pellet constitutes a meal if it is followed by drinking.

Stein (1964) hypothesized that rats do not adequately compensate for an increase in the number of drinking periods by reducing their intake per period. Regardless of the size or frequency of the meals, rats normally drink the same amount of fluid. Steller and Hill (1951) showed that rats drink at a constant rate. Rats either lick at the rate of six or seven licks per sec or they do not drink at all. The inability of rats to regulate post-pellet water consumption, and the fact that rats naturally drink at the end of a meal regardless of its size, seemingly account for the exaggerated drinking response exhibited in SIP. Falk (1966a) showed that SIP did not develop if the inter-pellet interval was less than 30 sec. It may be that a 30 sec period between pellets is necessary for a single pellet to serve as a "meal" in itself. Since, as Stein suggested, rats normally drink after a meal, the number of meals which the rat consumes in the test chamber is much greater than the 10 or so meals which rats normally obtain in their home cage (Hitzing, 1968). Since, as it is hypothesized, rats drink the same amount of water following a meal, regardless of the frequency or size of the meal (Stein, 1964), one may see that as the frequency of the meals increases, the total volume of fluid consumed also increases.

The meal hypothesis is closely related to the hypothesis based on thirst. Data on schedules of reinforcement and adventitious behavior do not necessarily mitigate against either the thirst or meal hypothesis. Falk (1966a) showed that the amount of fluid consumed was related to the length of the fixed interval. Longer intervals, up to a point, supported greater water intake. Segal and Deadwyler (1965) reported large amounts of water consumed during a DRL schedule of reinforcement. If rats normally drink the same amount of water each time they drink, one may legitimately question why one schedule of reinforcement supports more drinking than another schedule. The answers to such a question requires further empirical investigation, although for the moment, it is important to bear in mind the great effects which schedules of reinforcement may have in modifying ongoing behavior.

Purpose of the Present Experiment

Germane to the meal hypothesis is the notion that rats drink immediately following the consumption of food. If one goes by operational definitions, then there can be little fault with the notion of the meal hypothesis. As noted by Lester (1961), rats do not necessarily drink immediately after eating. It was noted that rats may wait as much as five hours after consuming food before drinking even though water is freely available. The physiological makeup of the rat allows for delays between eating and drinking. Wolf (1958) reported that rats may use endogenous water from their

tissues, body cavities, and metabolic processes during periods of water deprivation. Lepkovsky, Lyman, Fleming, Nanyuono, and Dimick (1957) claimed that a constant food-water ratio is maintained in the digestive tract of rats during water deprivation. These facts suggested a manner in which the meal hypothesis may be further examined. If the characteristic behavior of alternating between bar-pressing, eating, and drinking is related to the rat's normal home cage eating and drinking behavior, then it would seem reasonable to predict that rats who never had an opportunity to eat and drink together or in close succession would not display the characteristic alternating behavior when introduced into the test chamber.

The purpose of the present research is to determine if characteristic alternating between bar-presses, pellet consumption, and fluid consumption is related to pre-experimental patterns of eating and drinking with water and food available simultaneously. To fulfill this goal, it will be necessary to control the eating and drinking history of one group of rats and compare their performance in the test chamber with rats whose drinking and eating histories were undisturbed and who had free continual access to both food and water.

METHOD

Subjects

The subjects were 12 Sprague-Dawley albino rats weighing between 150 and 200 gm at the time of testing. The Ss were reared with their mother until 21 days of age. Litter size for the experimental and control groups were 11 and 12 pups respectively. Four of the six Ss in the control group were males while five of the six Ss in the experimental group were males.

Apparatus

The Ss were reared in slightly modified breeding cages. The breeding cages were rectangular 17 inch x 9 inch x 6 inch plastic cages with sanicel bedding and a removable metal grid lid. The food tray and water spout, located in spaces provided in the metal lid, were elevated, by means of plywood blocks, above the prescribed level so that the young pups were not able to reach the food or water. These essential nutrients could only be reached by the mother rat.

At six weeks of age, Ss were placed in individual home cages. These cages had metal grid and wire arrangements with a top which opened on a hinge. The cages were 9 inch x 12 inch x 9 inch in size. Food, present in food trays within the cages, consisted of regular laboratory rat chow. Water was available in a graduated 50 ml cylinder positioned by means of a ring stand and a clamp on

the outside of each cage. A metal water spout protruded a quarter of an inch into the cage. This arrangement permitted the experimenter (E) to visually monitor Ss' home cage water consumption.

In order to determine ad lib food consumption, the rat chow was ground into a fine powder and placed in a three inch bowl which was placed in turn in a large petri dish. These bowls were then placed in the cage. A square piece of paper was placed beneath the cage, directly under the area in which the bowls were placed, in order to determine how much, if any, of the powder was spilled by S. Food and water consumption was calculated daily. The food and bowls were weighed together each day to determine how much food was consumed.

The test chambers were two solid state Behavior Research Systems (BRS) Skinner boxes, multi programmer model number 2901. A false plexiglass side was placed in each box so that it was not necessary to drill holes for the water spout in the actual test chamber. This modification reduced the experimental space from 10 inches by 8 inches by 8.5 inches to 10 inches by 6 inches by 8.5 inches. A hole for the water spout was drilled in the false side three inches from the grid floor of the chamber. A 100 ml graduated cylinder was positioned, by means of the ring stand and clamp, in the space between the false side and the real side. The metal drinking spout did not protrude into the chamber so that S had to make contact with the tube with its tongue through the hole. The drinking spout was located on the wall adjacent to, and to the right of, the wall which contained the lever. The food magazine

was located to the left of, and along the same wall as, the lever. The distance between the water spout and the food magazine was five inches. The food pellets consisted of 45 mg Noyes pellets. Figure I illustrates the arrangement of the experimental space.

Procedure

The experimental group consisted of six rats reared under controlled eating and drinking conditions. The experimental Ss never had access to food and water together or in close succession. They were presented with food for five hours without water, followed by an hour in which neither food nor water was available, followed by five hours of water without food, which in turn was followed by an hour in which neither food nor water was present. The cycle was then repeated. This program was initiated at 15 days of age, while the pups were with their mother, and was continued through limited feeding and weight reduction programs until Ss were tested in the Skinner box. Appendix A shows the eating and drinking schedule in detail.

Rats were weaned at 21 days of age, placed in separate cages at 48 days of age, and reduced to 80 per cent of their pre-test body weight. The weight at 80 days of age served as a basis from which their reduced body weights were calculated. All Ss were gentled by daily handling for 15 sec a day starting from the time of weaning and continuing to the time of reduced feedings. Five days of gradual reduced feedings were followed by five days of

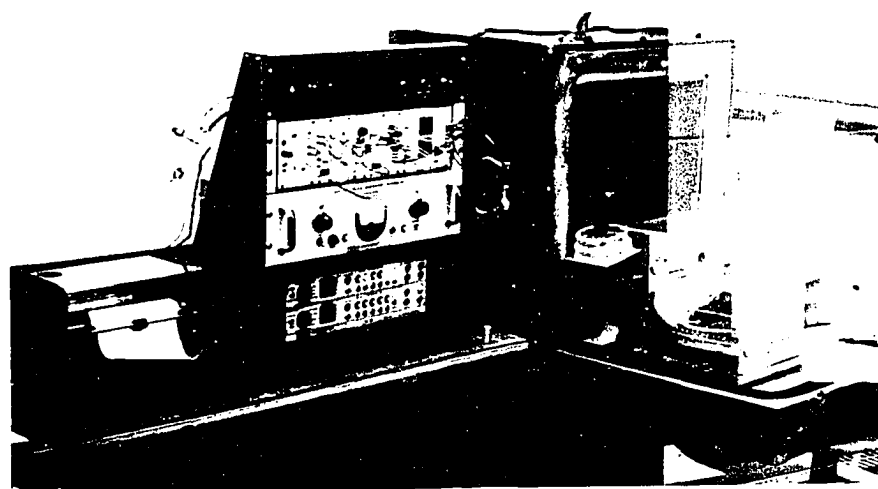
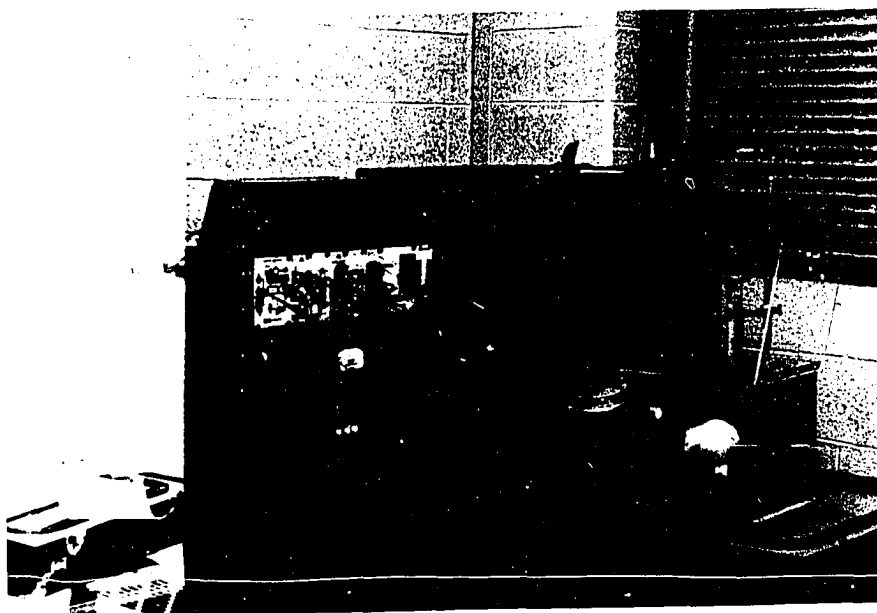


Fig. 1. Test chamber apparatus and arrangement.

measuring home cage drinking for Ss at reduced body weight. At 90 days of age, Ss were introduced to the test chamber. Home cage drinking data were collected throughout the course of the experiment, and daily limited feedings were employed to maintain Ss at 80 per cent of their pre-test body weights.

After 10 days of limited feeding and weight reduction, Ss were introduced to the experimental situation. For the first session, E recorded the number of bar-presses which S made and the amount of fluid it consumed in the 60 min session. No shaping by E occurred. Limited feedings were given in the home cage after each daily test session. The experimental group did not have access to water in the home cage for three hours after it was given the limited feedings. On the second day, Ss were magazine trained and were reinforced for successive approximations until they acquired the bar-pressing task on CRF. During the initial shaping session, Ss were free to respond until they received 150 pellets or 60 min had elapsed, whichever occurred first. On the third day, Ss responded on CRF to the criterion of 100 pellets or 60 min. The FI 50 sec schedule of reinforcement was developed on the fourth daily session. Starting on CRF, reinforcement was shifted to FI 10 after 10 pellets, FI 20 after 50 pellets, FI 30 after 80 pellets, and FI 50 after 110 pellets. Water was available, both in the test chamber and in the home cage, throughout the experiment; however, water and food were available together only in the test chamber.

Four daily sessions on FI 50 for 50 min and four sessions on FI 50 for 60 min were followed by an extinction session in which the pellet dispenser was electrically disconnected. The extinction session was followed on the subsequent day by a 60 min session on FI 50. The following daily session consisted of placing 75 pellets in the food magazine and disconnecting the pellet dispenser before placing S in the chamber. This permitted E to determine how much S would drink in the apparatus when the pellets were presented all at once rather than intermittently. A summary of the rearing and testing conditions is as follows:

Rats were reared with mother until 21 days of age.
 Pups could not reach the food or water until 15 days of age.
 Food and water alternated at 15 days of age.
 Rats placed in separate cages at 48 days of age.
 Weight at 80 days of age served as a basis for weight reduction.
 Five days of gradual reduced feedings to reduce S to 80 per cent of normal body weight were initiated at 81 days.
 Five days of measuring home cage drinking for Ss at 80 per cent of normal body weight initiated on day 86.
 At 90 days, S placed in test chamber without any shaping by E.
 On day 91, Ss were magazine trained and shaped on CRF.
 Day 92, Ss respond on CRF.
 Day 93, development of FI schedule.
 Day 94, start of four daily sessions on FI 50 for 60 min.
 Day 98, start of four daily sessions on FI 50 for 60 min.
 Day 102, extinction session.
 Day 103, FI 50 sec for 60 min.
 Day 104, 75 pellets placed in magazine prior to placing S in the chamber. Pellet dispenser not operable.

The control group consisted of six Ss who had food and water together simultaneously throughout the entire experiment. They were given limited feedings immediately after the experimental ses-

sion. Otherwise, the control group received the same treatment in the home cage as did the experimental group.

RESULTS

The purpose of the present research was to determine the effects of the past eating and drinking histories of the organism on the development of SIP. One group of rats, the experimental group, was reared under conditions in which they never had an opportunity to eat and drink simultaneously or in close succession. Another group, the control group, had water and food available simultaneously throughout the course of the experiment. In studies of this sort, where the experimenter manipulates eating and drinking patterns of Ss, there is always the possibility that the health and growth of the organisms would be impaired. Table 1 shows the weight of each S at 80 days of age, mean (\bar{x}) home cage food intake, and mean home cage water intake for Ss at full weight and for Ss at 80 per cent of their normal body weight.

The mean body weight for the experimental and control group was 205.0 gm and 213.5 gm, respectively. A two-tailed test of significance between means, using the Student's "t" for small groups, (Downey and Heath, 1959) showed that the average weight of Ss in each group was not significantly different. Since the control group contained two females and the experimental group contained one female, and since females are lighter than males, only four males from each group were included in the analysis. The weights of the males in the experimental group were 230, 218, 212, and 210

Table 1

Weight, in gm, of Ss at 80 days of age, mean home cage food intake, in gm, and mean home cage water consumption, in ml, for Ss at full weight and at 80 per cent of full body weight.

<u>Ss</u>	Weight in gm at 80 days	\bar{x} home cage food intake in gm	\bar{x} home cage water intake in ml (full body weight)	\bar{x} home cage wa- ter intake in ml (80 per cent of weight)
Experimental group				
E-1	230	17.7	30.7	19.8
E-2	218	19.2	26.9	18.2
E-3	212	17.3	29.0	20.3
E-4	210	18.7	32.3	17.7
E-5	200	15.8	35.5	20.7
E-6	160	15.8	27.5	12.6
Total	1230	104.5	178.9	111.3
\bar{X}	205	17.4	29.8	18.5
Control group				
C-1	162	15.2	23.9	16.0
C-2	243	22.8	30.0	20.1
C-3	165	14.9	24.6	17.7
C-4	243	20.6	28.3	21.2
C-5	238	20.0	28.7	22.5
C-6	230	20.9	28.4	19.8
Total	1281	114.4	163.6	117.3
\bar{X}	213.5	19.1	27.3	19.5

gm, and the weights for the controls were 243, 243, 238, and 230 gm. The females, E-6, C-1, and C-3 were nearly identical in weight, each weighing approximately 160 gm.

Home cage food consumption was measured by using powdered food seven days prior to reducing the animals to 80 per cent of their body weight. The control group consumed an average of 19.1 gm of food per day, and the experimental group consumed an average of 17.4 gm per day. A "t" test of significance between means for small groups, using four males from each group, showed that there was no significant difference in food consumption between the groups. Experimental Ss consumed an average of 17.7, 19.2, 17.3, and 18.7 gm of food per day, while the controls consumed 22.8, 20.6, 20.0, and 20.9 gm of food per day. The females, E-6, C-1, and C-3, consumed 15.8, 15.2, and 14.9 gm of food, respectively, per day.

The powdered food and petri dish arrangement allowed accurate monitoring of food intake. There was little or no food spilled on the collection sheet located beneath the cages. These data on food consumption are similar to data reported by Siegel and Stuckey (1947) who noted that rats normally consume an average of 22.9 gm of rat chow per day. The discrepancy between the food consumption data reported in the present paper and those reported by Siegel et al. may be attributed to differences in the size and age of Ss employed. Siegel's Ss ranged from 168 and 188 days and had a mean weight of 322 gm compared to 80 days and a mean weight of 209 gm for Ss used in the present study.

Mean water consumption at full body weight was similar for Ss in both groups, with group means of 29.8 ml and 27.3 ml of water for the experimental and control groups, respectively. In all cases, water consumption decreased when Ss were subjected to reduced feedings. At reduced weight, for the experimental and control groups, respectively, average water consumption was 18.5 and 19.5 ml per day. This represents a decrease from the above water consumption data for Ss at full weight. This positive correlation between water intake and food intake has been reported by Bolles (1961) and Grossman (1967).

Table 2 shows the amount of water consumed, in ml per kgm of body weight, for Ss in their home cages at reduced weight and in the test chamber on FI 50 for four 60 min sessions. Previous to the four 60 min sessions, there had been four sessions on FI 50 sec for 50 min. The mean home cage water consumption for the experimental and control groups, respectively, are 104.54 ml per kgm of body weight and 106.57 ml per kgm of body weight. Individual data are 101.38, 106.15, 113.93, 103.29, 133.84, and 68.67 ml per kgm of body weight for Ss in the experimental group and 112.59, 87.55, 126.81, 101.19, 109.16, and 102.15 ml per kgm for Ss in the control group. Group mean water consumption in the test chamber of FI 50 for 60 min sessions are 203.41 ml per kgm of body weight and 179.11 kgm of body weight for the experimental and control groups, respectively. Data for individual Ss are 178.54, 257.87, 218.41, 185.96, 182.42, and 197.26 ml per kgm of body weight for the experimental group and 204.54, 152.84, 220.82,

Table 2

Mean water consumption, in ml per kgm of body weight, for Ss at 80 per cent of full body weight, both in the home cage and in the test chamber on FI 50 sec for 60 minute sessions.

Mean home cage water intake (ml/kgm)		Mean test chamber water intake (ml/kgm) on FI 50 sec for 60 minutes	
Experimental group		Experimental group	
E-1	101.38		178.54
E-2	106.15		257.87
E-3	113.93		218.41
E-4	103.29		185.96
E-5	133.84		182.42
E-6	68.67		197.26
<hr/>			
Total	627.26	1220.46	"t" = 7.54 (significant at .001)
-			
X	104.54	203.41	
Control group		Control group	
C-1	112.59		204.54
C-2	87.55		152.84
C-3	126.81		220.82
C-4	101.19		166.24
C-5	109.16		148.43
C-6	102.15		181.81
<hr/>			
Total	639.45	1074.68	"t" = 6.55 (significant at .001)
-			
X	106.57	179.11	

166.24, 148.43, and 181.81 ml per kgm of body weight for Ss in the control group.

A "t" test of significance between means, 104.54 and 203.41 for the experimental group and 106.57 and 179.11 for the control group, for small samples and for correlated data (Downey and Heath, 1959) showed significant differences between home cage and test chamber water consumption, " t_s " of 7.54 and 6.55 for the experimental and control groups, respectively (significant at the .001 level of significance). These data compare one hour of drinking in the test chamber with 24 hour drinking in the home cage. There were no significant differences between means for the experimental and control group water consumption during SIP.

It was predicted that Ss who did not have a past history of eating and drinking in close succession would not alternate between food consumption and water intake in the test chamber. Rather, it was expected that such Ss would persevere in attempts to obtain the food pellets and not drink immediately following the ingestion of the food pellet. If such a prediction was accurate, then the experimental group should have made more bar-presses than the control groups. Table 3 shows the mean number of bar-presses made by S during four 60 min sessions of FI 50 sec of food reinforcement. The mean number of presses for the experimental group is 529 and the mean for the control group is 525. A "t" test of significance between means for small samples and uncorrelated

Table 3

Mean bar presses by S on
FI50 sec for 60 minute sessions

Experimental group	Control Group
E-1 426	C-1 323
E-2 448	C-2 450
E-3 455	C-3 536
E-4 396	C-4 620
E-5 528	C-5 741
E-6 919	C-6 479
<hr/>	
T-3172	T-3149
\bar{X} -529	\bar{X} -525

data failed to show a significant difference between the groups.

Figure 2 shows the mean drinking data for the experimental and control groups during each phase of the experiment. The data are presented in terms of ml of water consumed. The average water consumption for each S was calculated, and these data were averaged to determine the mean water consumption for the group. Both groups showed the expected decrease in water consumption during limited feeding. Neither group displayed excessive water consumption during the shaping sessions on CRF, average consumption being 5.3 ml and 6.5 ml for the control group and the experimental group, respectively. Drinking increased for each group when the intermittent schedule was initiated. Water consumption increased and became excessive, when compared with baseline data for Ss at reduced weight, when the FI 50 sessions were initiated.

Subjects in both groups consumed more water in the 60 min session than in the 50 min session. Review of the literature shows that water consumption increases with longer sessions as long as Ss are food deprived and continue to receive pellets on an intermittent schedule of reinforcement. During the extinction session, water consumption diminished to 1.1 ml and .25 ml for the experimental and the control groups, respectively. Excessive drinking resumed when the FI 50 schedule was reintroduced. When 70 pellets were placed in the magazine at one time and the pellet dispenser was made inoperable, water consumption decreased to 4.5

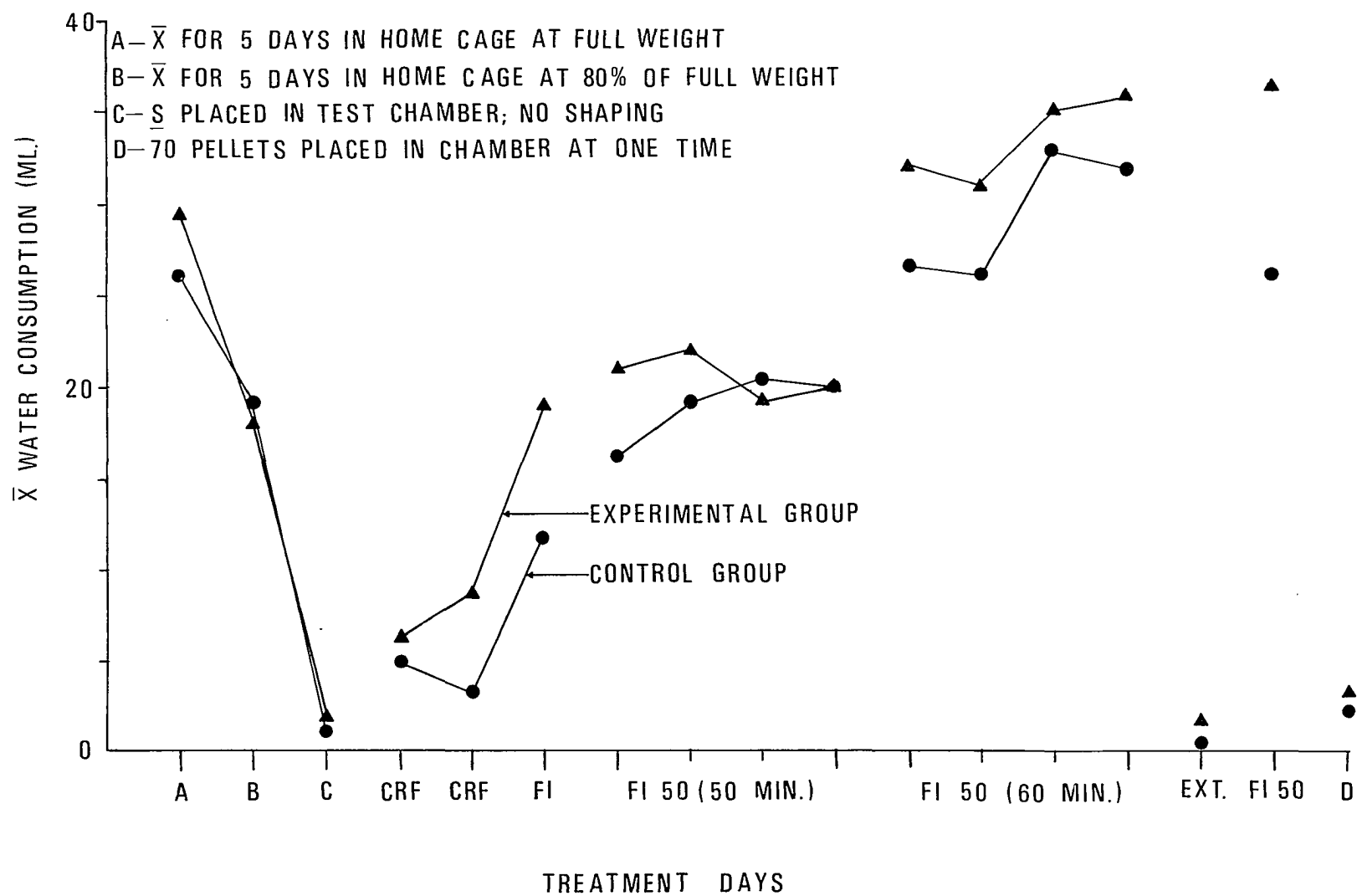


Fig. 2. Mean water consumption (ml.) for each group of \bar{S} s during each experimental condition.

ml and 3.25 ml for the experimental and control groups, respectively. This demonstrates that intermittent presentation of food pellets is necessary for SIP.

DISCUSSION

As noted by Lester (1961), a striking characteristic feature of SIP is the consistent manner in which rats alternate between ingesting the food pellets and drinking from the water spout. Recent researchers (Stein, 1964; Schaeffer and Diehl, 1966; Falk, 1967) hypothesized that the alternating behavior was related to past patterns of drinking water after ingesting food. In summary, it was believed that the excessive nature of water consumption in the test chamber was due to the fact that rats ordinarily drink at the end of a meal, and that when rats drink water, they drink about the same amount each time regardless of the size or frequency of the meals. In order to further analyze the meal hypothesis, rats were reared under conditions in which they never had access to food and water simultaneously or in close succession. Their food and water consumption, both in the home cage and test chamber, was compared to controls' who had access to food and water together throughout the course of the experiment.

The controlled eating and drinking history did not impair the growth or health of Ss. There were no significant differences in home cage food and water consumption between the experimental and control groups. Drinking and eating data for both groups were in close agreement with previously published data (Siegel and Stuckey, 1947; Siegel, 1949; Bolles, 1961). Both groups consumed about 25 ml of water and 20 gm of food per day. When Ss were given limited

feedings, water consumption decreased accordingly. Since the experimental group did not differ significantly from the control group with respect to home cage food and water intake, Lester's (1961) observation that it is not necessary for rats to drink immediately following the ingestion of food in order to digest the food and remain healthy appears to be correct.

Certain differences between the experimental and control groups need to be clarified. Whereas the control group ate and drank in a "casual" manner over long periods of time, experimental Ss consumed the food and water in a vigorous manner, consuming their full five hour complement of food in approximately one hour and of water in about 15 minutes. These differences may be due to the fact that experimental Ss were alternately food and water deprived throughout the course of the experiment. Bolles (1961) noted that as the length of deprivation increases, eating spurts and drinking bursts increase in duration. It is also noteworthy that food and water deprived rats did not consume their 24 hour complement of food and water within the five hours in which these commodities were available. Bolles (1961) noted that rats given limited daily access to water and food never consumed their entire supply at once. Rather, they ate and drank a given amount and stopped. In this manner, food and water deprived rats remained deprived, at least with respect to 24 hour baseline data, when they were given access to food and water for one hour per day.

Despite differences in the home cage eating and drinking

histories of the two groups, both groups exhibited the characteristic behavioral aspects of schedule-induced polydipsia in the test chamber. They consumed excessive amounts of fluid and displayed the characteristic alternation between pellet ingestion and water consumption. If performance in the test chamber was related to the past history of Ss, one might predict that experimental Ss, who never drank following the ingestion of food in the past, would continue to press the bar and persevere in attempts to obtain food to a greater degree than controls who had a history of drinking after a meal. To the contrary, both groups displayed the characteristic alternating behavior when the intermittent food schedule was introduced and proceeded to consume excessive amounts of water with no significant differences in the mean number of bar-presses per session.

The present study showed that alternating between eating and drinking in the test chamber was independent of alternating between eating and drinking in the home cage. Advocates of the meal hypothesis attempt to explain SIP on the basis that the characteristic alternating behavior is due to the fact that rats normally drink a certain amount of water immediately following the ingesting of food. The results from the present experiment mitigate against such a connection. However, it should be noted that it is possible that eating and drinking patterns become established early in the life of the organism. It is possible that the young pups, while they were still housed with their mother, ate solid rat chow and then drank milk from the mother. It should be noted, however, that all

of the pups consumed water in a vigorous fashion, fighting one another for position, when the water bottle was introduced at the appropriate time. Eating and drinking patterns, if not phylogenetically determined, may be acquired at a very early age. For example, although the young pups could not reach the food and water until 15 days of age, they were in an environment where the mother rat displayed normal eating and drinking behavior.

It is also possible that SIP is a general phenomenon that is not unique to fluid consumption. Villiard and Falk (1967) showed that monkeys ingest wood shavings during the inter-pellet interval. An atypical case encountered by the author (Freed and Hymowitz, 1967) showed a rat that chewed the paper beneath the cage during the inter-pellet interval. When the paper was removed, S consumed large quantities of water in typical SIP fashion.

In an analysis of the motivating properties of SIP, Falk (1967) introduced the term "adjunctive" behavior to describe SIP. Calling SIP adjunctive does not explain the phenomenon, although it does provide some insights into directions which further research may follow. Adjunctive behaviors are behaviors which acquire reinforcing properties due to their close interaction with other behaviors which are under the control of certain schedules of reinforcement. Falk (1967) showed that polydipsia occurred on VI one minute food schedules when water was concurrently available on bar-press FI schedules rather than being freely available. The motivating properties of water during SIP certainly warrant further

investigation, the implication being that SIP may be just one example of many seemingly unexplainable behaviors, such as Azrin's aggression (1964) and self-mutilation behaviors such as head banging which are consistent and motivational in nature although researchers have been at a loss in determining the precise controlling variables.

Schedule-induced polydipsia has proven to be an interesting and worthwhile area of investigation. It has proven to be a useful technological tool in work with water and alcohol consumption. In the future, SIP may be employed in drug research where, for example, morphine may be substituted for the available fluid. However, before SIP can be used as a precise methodological tool, it is necessary to understand the many variables involved in SIP. The present paper showed that interpretations of SIP in terms of the "meal" hypothesis may be premature. To be sure, more research is required before this hypothesis can be accepted or rejected. Certainly, current research in this area point out the need for more data on the normal drinking patterns of rats in their home cage. Information on the frequency of alternation between eating and drinking in the home cage, the consistency and latency involved in such alternation, and the amount of water consumed with respect to frequency and size of meals is of utmost importance in understanding the phenomenon of SIP.

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Appendix A

Food and water schedule for the experimental group

7 AM - 8 AM	No food or water
8 AM - 1 PM	Food
1 PM - 2 PM	No food or water
2 PM - 7 PM	Water
7 PM - 8 PM	No food or water
8 PM - 1 AM	Food
1 AM - 2 AM	No food or water
2 AM - 7 AM	Water