# REINFORCER MAGNITUDE AND SCHEDULE-INDUCED POLYDIPSIA

# THE EFFECTS OF WITHIN-SESSION MANIPULATION OF REINFORCER MAGNITUDE ON SCHEDULE-INDUCED POLYDIPSIA

by

Paula E. Pasquali

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Arts.

Department of Psychology
McGill University
Montreal

March, 1976

# ABSTRACT

M.A. Psychology

Paula E. Pasquali

## THE EFFECTS OF WITHIN-SESSION MANIPULATION OF REINFORCER MAGNITUDE ON SCHEDULE-INDUCED POLYDIPSIA

Schedule-induced polydipsia is characterized primarily by the distinct temporal topography in which the drinking occurs during the intervals between successive, spaced food presentations. The present study outlines and examines an account of this phenomenon in terms of frustration, an emotional-motivational state induced by the delay in the availability of the next expected food presentation. Assuming that the magnitude of the next expected food delivery is directly related to the degree of induced frustration, it may be predicted that the amount of adjunctive drinking would increase as the magnitude of the expected food presentation increases. Contrary to this prediction, two experiments, each with four rats, showed that it is the quantity of food just ingested, and not the magnitude of the next expected food delivery that determines the amount of adjunctive drinking. Another finding was that less drinking followed the ingestion of the larger quantity of food. A possible explanation for these results is explored in terms of time allocation of responding as a function of the momentary conditioned incentive value of particular situational stimuli.

M.A. Psychologie

# EFFETS DE LA MANIPULATION DE LA MAGNITUDE DU RENFORCEMENT A L'INTERIEUR DE LA SESSION SUR LA POLYDIPSIE INDUITE PAR LE PROGRAMME D'ALIMENTATION

Paula Pasquali

La polydipsie induite par le programme d'alimentation est caracterisée principalement par la topographie temporelle particulière avec laquelle la consommation d'eau survient pendant les intervalles séparant les présentations successives de nourriture. La présente étude décrit et examine une approche de ce phénomène en terme de frustration, un état émotionnel et motivationnel induit par un délai dans la disponibilité de la prochaine présentation attendue de nourriture. En considérant que la magnitude de la prochaine distribution attendue de nourriture est directement reliée au degré de frustration induite, on pourrait s'attendre à ce que la quantité de consommation d'eau croisse avec l'augmentation de la magnitude de la présentation attendue de nourriture. Contrairement à cette prédiction, deux expériences, chacune avec quatre rats, ont montré que c'est la quantité de nourriture just ingerée, et non la magnitude de la prochaine distribution attendue de nourriture, qui détermine la quantité de consommation d'eau. Un autre résultat à été que l'ingestion d'une plus grande quantité de nourriture est suivie de moins de consommation d'eau. Une explication possible de ces résultats est explorée en terme de temps de réponse alloué, en tant que fonction de la valence conditionnée momentanée des stimuli situationnels particuliers.

# ACKNOWLEDGEMENTS

Foremost, the author wishes to express her gratitude to Dr. D. Bindra for his critical comments during the preparation of this manuscript. Thanks are also due to Ms. A. Wydra for personal support, and Ms. R. Amsel and Dr. J. Ramsey for statistical advice. This research was supported by Grant No. 28324 awarded to Dr. J.R. Millenson by the National Research Council of Canada.

# TABLE OF CONTENTS

Page No.

EXPERIMENT 1A

EXPERIMENT 1B

# INTRODUCTION

A good deal of recent work has shown that various reinforcement schedules not only influence the frequency and pattern of the target response that is explicitly reinforced but may also modify the probability and temporal topography of "extraneous" behaviors, different from the target response. These other responses, which are observed to occur during the inter-reinforcement interval, are collectively referred to as adjunctive behavior. Perhaps the most dramatic example of adjunctive behavior is schedule-induced polydipsia--the excessive drinking which develops under a variety of schedules of intermittent reinforcement for food. The present study proposes and tests a time-sharing account of this phenomenon which attributes the occurrence and degree of adjunctive drinking to the interaction of the intermittence of food presentation and the frustration generated by the schedule of reinforcement. Before discussing the experimental findings on schedule-induced polydipsia and introducing the time-sharing model, it may be useful to outline the main defining characteristics of adjunctive behavior.

## Adjunctive Behavior

If a running wheel is made available to rats engaged in bar-pressing for food pellets on a Fixed Interval (FI)-5 minute schedule of reinforcement, a burst of running lasting up to three minutes occurs following the presentation of a food pellet, prior to the resumption of bar-pressing leading to the next reinforcement (Skinner and Morse, 1957). This observation received little, if any, attention at the time it was published. Subsequently Falk (1961) noted that rats lever-pressing on a Variable Interval (VI)-1 minute schedule of reinforcement for food drank almost 3-1/2 times their normal daily water intake in a single experimental session of approximately 3 hours. Like the wheel-running observed by Skinner and Morse, the drinking occurred post-pellet (that is, after the ingestion of a food pellet), with high frequency and in a regular temporal topography. As these animals had no history of water deprivation, the excessive, and therefore anomalous, nature of post-pellet drinking has led many investigators to examine in detail the nature of adjunctive behaviors.

Besides such "psychogenic polydipsia" (Falk, 1969) and schedule-induced wheel-running (Levitsky and Collier, 1968) several other types of responses have been shown to occur during the inter-reinforcement interval prior to the occurrence of the target response. These include responses such as aggressive attack (Gentry, 1968), cellulose-eating (Freed and Hymowitz, 1969), air-licking (Mendelson and Chillag, 1970), tail-gnawing (Laties, Weiss, Clark and Reynolds, 1965), nitrogen-licking (Taylor and Lester, 1969), and wood-gnawing (Killeen, 1975). The essential feature of adjunctive behaviors is the increased probability with which they occur during the inter-reinforcement interval (IRI) in the absence of any experimenter-arranged contingency which would explicitly reinforce their occurrence. Additionally, they are initiated immediately succeeding the ingestion of the reinforcer--at a time when the probability of further reinforcement is near-zero. Formally, adjunctive behavior has been defined as a class of behaviors "maintained at high probability by stimuli whose reinforcing properties in the situation are derived primarily as a function of schedule parameters governing the availability of another class of reinforcers". (Falk, 1971, p. 586)

The necessary schedule parameter appears to be one of intermittence of reinforcement: the occurrence and degree of adjunctive behavior depend at least to some extent upon the duration of the IRI. Demonstrations of adjunctive behavior have usually employed interval schedules where the duration of the IRI is explicitly controlled by the experimenter. In general, a minimum interval of 30 seconds between reinforcements is required. It is not surprising then that adjunctive behaviors do not occur under continuous reinforcement (CRF) schedules (Falk, 1966a) or Fixed Ratio (FR) schedules of small magnitude (Burks, 1970); in these cases the average inter-reinforcement interval is apparently too small. Polydipsia, however, has been demonstrated under FR 40 and FR 80 schedules (Burks, 1970); since a given amount of time elapses as the prerequisite number of operants is emitted, these schedules, like interval schedules, result in providing the minimum time between reinforcers required for the occurrence of adjunctive behaviors. However, as is the case with all ratio schedules, the overall rate of reinforcement is strictly a function of the animal's rate of performing the operant; accordingly, engaging in an adjunctive behavior necessarily decreases the reinforcement rate. But as the ratio requirement increases, the _relative_ degree to which the occurrence of an adjunctive behavior degrades the reinforcement rate decreases. And, in fact, sessional drinking increases as a function of the FR requirement (Schaeffer and Diehl, 1966). This suggests that the occurrence of an adjunctive behavior may partially depend upon _whether_ and to _what extent_ there occurs a decrease in the maximum reinforcement rate. That adjunctive behaviors occur under interval schedules and large, but not small, ratio schedules is thus understandable; the effect of adjunctive behavior on overall reinforcement rate, however, remains to be systematically investigated.

It is important to note that the schedule-induced behaviors reported above have been observed most often under food reinforcement schedules with rats maintained below 95% of their free-feeding weights (Falk, 1969; Chillag and Mendelson, 1971).

Attempts at inducing adjunctive behaviors in the rat under schedules of reinforcement for intra-cranial stimulation (Cohen and Mendelson, 1974; Ramer and Wilke, 1975) and water (Carlisle, Shanab, and Simpson, 1972) have met with little success. When the opportunity to wheel-run is the reinforcer, adjunctive rearing may be observed (Singer, Wayner, Stein, Cimino and King, 1974).

## Schedule-Induced Polydipsia

Although most of the research on schedule-induced polydipsia has used rats as subjects, the phenomenon is not species-specific; it has also been demonstrated in the rhesus monkey (Schuster and Woods, 1966), the gerbil (Kutscher, Stillman and Weiss, 1968), the pigeon (Shanab and Peterson, 1969) and the mouse (Palfai, Kutscher and Symons, 1971). It is easily obtainable under a variety of schedules of intermittent reinforcement (most notably Fixed Interval, Variable Interval, Fixed Time and Variable Time schedules) with a multitude of food reinforcers. The phenomenon is not restricted to water ingestion, for solutions of saline (Falk, 1966b), saccharine (Keehn, Colotla and Beatton, 1970), quinine sulfate (Segal and Deadwyler, 1965a), and ethanol (Falk, Samson, and Winger, 1972) are also readily and excessively consumed.

The development of polydipsia exhibits a typical acquisition curve which is independent of adaptation to the food schedule. If water is unavailable in the test situation until performance on the food schedule has stabilized, the acquisition of polydipsic drinking is not altered (Reynierse and Spanier, 1968). When the drinking solution is available throughout the experimental session, polydipsic drinking typically occurs post-pellet, in a single uninterrupted burst of licking beginning immediately after ingestion of the reinforcer (Keehn and Colotla, 1970). However, even when the opportunity to drink is restricted to certain portions of the IRI, sessional water intake remains high; that is, polydipsic levels of drinking are maintained if the opportunity to drink does not exist immediately after the ingestion of the pellet. For instance, on a FI-1 minute schedule of reinforcement for food, when the availability of water is limited to three of the four 15-second quarters (Flory and O'Boyle, 1972) or the last 30 seconds of the interval (Gilbert, 1974), the amount drunk is only slightly attenuated.

The temporal topography of the drinking is such that when the IRI is between 40 and 60 seconds, most of the drinking occurs during the first 20-30 seconds of the interval (Gilbert, 1974; Schaeffer and Salzberg, 1973; Burks, Hitzig, and Schaeffer, 1967). Although no parametric study of the relationship between the duration of the IRI and the distribution of drinking during the interval has been reported, it is clear from inspection of cumulative records that there is profuse drinking soon after the delivery of the reinforcer which terminates well before the interval has elapsed. It has been observed that when water is available on a CRF schedule during Fixed Time (FT) schedules for food reinforcement, responding for water approximates a normal distribution with the maximum occurring midway through the interval (Killeen, 1975). Moreover this latter distribution is independent of interval length.

The magnitude of polydipsia as measured in sessional fluid intake is a function of the intermittency of reinforcement. Falk (1966c) conducted the first systematic investigation of the relationship between the duration of the IRI and the magnitude of polydipsic drinking. Using FI schedules ranging from 2 to 300 seconds, with the number and size of the reinforcers constant, a bitonic (inverted-U shaped) function relating the minimum IRI to total fluid intake was reported. The amount of water consumed in a single session increased monotonically up to a maximum at FI-90 seconds for one subject and FI-180 seconds for the other, decreasing monotonically thereafter. A similar function has been found relating the IRI of Variable Time (VT) schedules to sessional fluid intake (Hawkins, Schrot, Githens, and Everett, 1972). The relationship between sessional drinking and FT schedules is less clear. Wayner and Greenberg (1973) report a bitonic function which increases up to a maximum at FT-4 minutes whereas Hawkins et al. (1972) report equivocal results.

When the size of the reinforcer is held constant, manipulation of the duration of the IRI is confounded with variations in the consummatory rate; that is, as the interval length increases, consummatory rate decreases and vice versa. The question arises then whether it is the IRI per se or the consummatory rate which is responsible for the differential amounts of drinking. By increasing the number of pellets per reinforcer and simultaneously varying the IRI (thereby maintaining a constant consummatory rate), Bond (1973) found differential amounts of drinking. These results are difficult to interpret as in this experiment the duration of the IRI is confounded with reinforcer size; however it is plausible that the duration of the IRI per se, and not consummatory rate, is responsible for the bitonic function.

It is interesting that when a second measurable activity is concurrently made available to the subject, drinking may be displaced within the IRI. Killeen (1975) found that when water and a wood block were simultaneously available to rats on an FT-75 second schedule for food, gnawing occurred prior to drinking. Conversely, when drinking and wheel-running are available, drinking precedes running during the IRI (Segal, 1969; Staddon and Ayres, 1975). Similarly Hymowitz (1971) and Knutson and Schrader

(1975) found that when attacks upon a target subject occurred, they followed the post-pellet drinking. These results suggest that the activities which function as adjuncts may be hierarchically ordered. It is proposed, perhaps prematurely, that the differences in the temporal location of these activities are reflective of the differential reinforcing properties of these activities. Implicit in this suggestion is the notion of prepotency. That is, there may be an a priori probability associated with the occurrence of each adjunct, and in conjunction with the stimulus conditions present, these probabilities determine which adjunctive behaviors will occur and in what temporal sequence. Consequently some activities which function as adjuncts may be more prepotent than others for a given reinforcer. For example, drinking may be a prepotent response to spaced presentation of food. The finding that rats prefer situations where the opportunity to drink exists over situations where the same schedule of reinforcement for food is in effect but water is unavailable (Cohen, 1975) is consistent with this suggestion. One can extend the concept of prepotency further and postulate that the failure to see adjunctive behaviors when ICS or water are used as reinforcers is due to the inaccessibility of appropriate, or prepotent, activities.

## Physiological Interpretations

Several attempts to explain schedule-induced polydipsia have sought a physiological mechanism as a basis of the phenomenon. The notion of thirst-invoked drinking has often been proposed (Stein, 1964; Teitlebaum, 1966). Falk (1964) showed that food deprivation leads to a decrease in fluid intake in the rat, so that drinking between food reinforcers might serve a compensatory function by repleting the body's store of fluids and thus facilitating the ingestion of dry food. However, Stricker and Adair (1966) have shown that polydipsic drinking leads to considerable tissue over-hydration: the excessive nature of the drinking then would seem to rule out a strictly homeostatic mechanism.

Thirst-invoked hypotheses are also unable to explain: (1) the polydipsia that develops on schedules of reinforcement for liquid foods (Falk, 1967; Hawkins et al., 1972) and (2) the bitonic function relating the minimum IRI to sessional fluid intake. Additionally, the very fact that adjunctive drinking follows an extinction curve when the pellet dispenser is operative but food is not delivered (Segal and Deadwyler, 1965b; Segal, Oden and Deadwyler, 1965) as well as an acquisition curve argues against a thirst-invoked interpretation. Moreover the drinking that occurs upon completion of each FI component of a second-order schedule (Rosenblith, 1970) and non-reinforced intervals of percentage reinforcement schedules (Porter and Kenshalo, 1974) cannot be explained. In sum, the evidence suggests that thirst is at best only one of many factors contributing to the development and maintenance of schedule-induced polydipsia.

More recently Carlisle (1971) has examined the relationship between body temperature and polydipsia, tentatively suggesting that drinking may have a thermo-regulatory function. Drinking was found to correlate with a decrease in hypothalamic temperature whereas drinking pauses were accompanied by a rise in temperature. However the differences in either direction were slight and the research to date has revealed a correlational and not any causal relationship.

If adjunctive behavior is to be considered a genuine category of behaviors, one would hope for an explanation of schedule-induced polydipsia which can account for the occurrence of diverse forms of behaviors classified as adjunctive. In this respect, general behavioral hypotheses would be preferable to physiological interpretations which are specific to schedule-induced polydipsia.

## Behavioral Hypotheses

Clark (1962) proposed that polydipsia is a "superstitious" behavior (Skinner, 1948) resulting from the adventitious reinforcement of the licking response. He argued that for short intervals of a VI series, licking that is closely followed by a reinforced operant is likely to be reinforced as well. Several objections can be raised against this interpretation. Polydipsia has repeatedly been demonstrated on schedules not employing short intervals (e.g., FI schedules). If licking were superstitiously reinforced, then drinking should increase towards the end of the IRI with little drinking immediately post-reinforcement. This prediction does not agree with the observed lick distribution. When, in fact, licking is explicitly reinforced with food on a FI schedule, two distinct patterns of licking develop: post-pellet (polydipsic) drinking and then the typical FI scallop (Segal and Deadwyler, 1964). On the other hand, procedures which explicitly prevent contiguity between licking and the reinforcer (via time-outs from reinforcement) do not necessarily prevent the development of polydipsia (Segal and Oden, 1969). Finally, licking terminates when the water spout is dry (Stein, 1964) contrary to a prediction of the "superstitious" hypothesis.

Under schedules of reinforcement which arrange for a reinforcer to be delivered on a CRF schedule provided the inter-response time exceeds a minimum value (DRL schedule), drinking has been found to facilitate the spaced responding required by this schedule (Segal and Holloway, 1963). Thus it is possible that drinking may serve a timing function. This timing interpretation could account for polydipsic drinking on DRL (Segal and Deadwyler, 1965b) and possibly FI schedules, as well as for the increasing portion of the bitonic function. However, it clearly cannot explain drinking on FT and VT schedules where the presentation of food is independent of the subject's behavior. Moreover it would predict a positive linear function, not a bitonic function, relating FI value to the amount of inter-reinforcement drinking.

The tendency of rats to drink after each meal has been used to explain schedule-induced polydipsia (Reynierse, 1966; Lotter, Woods and Vasselli, 1973). It is known that non-deprived rats alternate between drinking and eating, with each eating session followed by a drinking burst (Kissileff, 1969). Similarly, rats that are both food- and water-deprived alternate between bursts of drinking and eating, after an initial drinking bout which serves to ameliorate the deficit (Hamilton and Flaherty, 1971). Lotter et al. suggest that a fixed amount of water is consumed after each meal "independently of the size" (p. 478) on schedules of intermittent reinforcement. This implies that as the number of meals increases (that is, as the size of the meals decreases), sessional drinking should also increase and therefore polydipsic drinking is merely an artifact of the number of meals. However, as Millenson (1975a) has pointed out: (a) this hypothesis does not predict the inverted-U function obtained when the IRI is plotted against sessional drinking, and (b) the data presented by Lotter et al. show that as the size of the meal increases the amount of water consumed after each reinforcer also increases.

It is clear that any adequate account of polydipsia must take into consideration the motivational properties of schedule-induced drinking. A major flaw in the hypotheses presented above lies in their inability to account for the behavioral evidence indicating that the polydipsic animal is highly motivated to drink.

## Motivational Properties of Schedule-Induced Polydipsia

Falk (1966a) reported that rats bar-press up to FR 50 for 0.1 milliliters of water and in so doing maintain a polydipsic level of drinking. On schedules which typically lead to high water intake, the animal will consume comparable amounts of solutions which are often avoided (e.g., ethanol: Mello, 1973). Lick-contingent delays of reinforcement (time-outs) of 30 and 60 seconds do not prevent the development of polydipsia (Segal and Oden, 1969). Similarly Flory and Lickfett (1974) found that time-outs of 10, 20 and 40 seconds only mildly suppressed the polydipsia that had developed on an FI-60 second schedule. The degree of suppression was proportional to the duration of the time-out, ~~but in~~ all cases sessional drinking was elevated above baseline. Only in the case of an 80 second time-out was drinking sufficiently suppressed below baseline. Similarly time-outs of 4 minutes prevent the development of polydipsia on an FT-60 second schedule (Hawkins et al., 1972). In both these cases, the delay of the subsequent reinforcer was greater than the minimum IRI. It is not possible therefore to ascertain whether it is the absolute or relative duration of the time-out that determines to what degree drinking will be suppressed. And finally, the finding that it is difficult to establish a conditioned taste aversion in polydipsic animals (Roll, Schaeffer and Smith, 1969) is suggestive of a highly motivated organism. After polydipsia had developed with water as the drinking solution, a saccharine solution was substituted and subsequently paired with toxicosis. On the following day, saccharine intake remained high, a finding which is surprising in view of most of the literature on conditioned taste aversions.

Falk (1969) and subsequently Wuttke and Innis (1972) have implicated an important role for the motivational state of the animal in noting the similarity between schedules under which polydipsia occurs and situations in the wild which lead to displacement activities (Tinbergen, 1952). In both instances, the animal is prevented from attaining a goal object and a behavior which seems inappropriate in the context is observed. It has been suggested (Staddon and Simmelhag, 1971; Wuttke and Innis, 1972) that in these situations consummatory behaviors unrelated to the goal object are emitted due to a disinhibition of the corresponding motivational system. While this approach has intuitive appeal and descriptive value, it has little predictive power.

There have been suggestions that the emotional state induced by the food regimen (Segal, 1972), and more specifically frustration (Falk, 1971), is responsible for the drinking which is observed under schedules of intermittent reinforcement for food. More recently Millenson (1975b) has also implicated frustration as the motivational basis of adjunctive drinking. He proposed a time-sharing account of schedule-induced polydipsia which attributes the occurrence and degree of adjunctive drinking to the interaction of two factors: the time available to the organism to drink between successive food deliveries and the frustration induced by the spaced presentation of food.

As the mean interval between successive food deliveries increases, the organism is able to engage in greater bouts of drinking without noticeably decreasing the food reinforcement rate. It is reasonable that this should be one variable which influences the amount of inter-reinforcement drinking; however, noting that there is time available for drinking does not explain why drinking, in fact, occurs.

A motivational factor, frustration, is postulated and is presumed to interact with the time factor. The term frustration is used here to refer to an emotional-motivational state

(Millenson, 1971) induced by a period of non-reinforcement following the delivery of a reinforcing stimulus. This usage of the term is not unlike that of previous theorists (e.g., Amsel, 1958; Mowrer, 1960). It is assumed that conditioned frustration results from the perception of environmental and temporal stimuli that come to be associated with non-reward through a process of classical conditioning and that this conditioned emotional state, like frustration, is aversive. Under those schedules which typically lead to adjunctive behaviors, there is a period following each reinforcing event during which further reinforcement is improbable. By definition this period of non-reinforcement is frustrating and adjunctive behaviors are thought to be byproducts of the induced frustration. It is important to note that this motivational account of schedule-induced polydipsia assumes that the unavailability (or delay) of the <u>next</u> reinforcer is the generative condition of frustration. It follows from this assumption that the amount of frustration (and hence, the amount of drinking) should be influenced by the relative reinforcing value of the next scheduled food delivery; that is, more frustration should be induced when the value of the upcoming reinforcer is enhanced. The observations that the amount of inter-reinforcement drinking is greater when 2 pellets (Flory, 1971) and 4 pellets (Couch, 1974) are substituted for single pellets may be interpreted in this way. However, in these experiments all food deliveries within a session were of equal size, and hence, the motivational effects of the magnitude of the ingested reinforcer and the magnitude of the next expected reinforcer are confounded.

In the present study, a direct test of the effects of reinforcer magnitude on drinking during the preceding IRI was conducted. In a within-session design, two different quantities of food were delivered such that the time between successive food presentations was constant and the size of the reinforcer was predictable. If, as hypothesized, the expected reinforcer size affects the amount of frustration, more drinking should be observed during the IRI preceding the delivery of the larger quantity of food.

# EXPERIMENT 1A

In the following experiment, food was available to rats on a Fixed Time (FT) schedule. Either one or four pellets were delivered upon each scheduled food presentation such that every third reinforcement consisted of four pellets. The number of pellets presented on successive reinforcements was therefore 1, 1, 4, 1, 1, 4, etc. Of critical importance is the drinking observed during the IRI separating the delivery of the two single pellets as contrasted to the drinking during the IRI preceding the delivery of four pellets. These IRIs are of equal duration and for both intervals the ingested reinforcer is a single pellet. Any differential drinking would thus be attributable to the expected size of the upcoming reinforcement.

## METHOD

### Subjects

Four experimentally naive male Long Evans hooded rats served as subjects. The Ss, initially weighing 375-400 g, were reduced to 80% of their free-feeding weights prior to the onset of experimentation. Each S was housed individually with water available ad lib. Sessional food intake was supplemented with small portions of Purina Lab Chow given in the home cage to maintain the 80% body weight.

Apparatus

The experiment was conducted in four identical Behavior Systems operant conditioning chambers, each enclosed within a sound-attenuated and light-shielded shell. Ventilation and masking noise were provided by a fan located within each shell. Each test chamber was 21.5 x 24.5 x 19.5 cm with a front wall of Plexiglas; the remaining walls, ceiling and floor grids were stainless steel. A light bulb, centered in the ceiling, provided illumination. A stainless steel drinking spout was mounted 3.5 cm above floor level on the far right of the front wall, protruding approximately 2.5 cm into the experimental chamber. A 100-ml graduated cylinder was attached to the drinking spout to allow measurement of sessional water intake. Centered in the left adjacent wall, 0.5 cm above floor level, was a food magazine (5.0 x 6.5 cm) into which 45-mg Noyes pellets were delivered. To either side of the magazine were inoperative levers; above each lever and the food magazine were stimulus lights, also inoperative.

Licks were monitored via drinkometer circuits; scheduling and data recording were controlled by a PDP-11 digital computer operating under ACT-N (Automated Contingency Translator: Millenson, 1975c).

Procedure

Following three days of magazine training, the Ss were placed on a Fixed Time (FT)-2 minute schedule for food. This schedule arranges for a reinforcer to be delivered every two minutes, independent of the S's behavior. The reinforcer consisted of either 1- or 4-45 mg Noyes pellets delivered in the following regular sequence: every third reinforcement consisted of four pellets, the two preceding food presentations consisting of 1 pellet each. This cycle (1, 1, 4) was repeated eight times on three consecutive days. Subsequent sessions consisted of twenty-five repetitions of this cycle, terminating after 2.5 hours. The beginning and end of each session were signalled by the onset and offset of the houselight.

Sessional water intake and licks per post-reinforcement interval were recorded.

## RESULTS

During the early experimental sessions, total water consumed per session increased daily, reaching stabilization for all subjects by the 15th session. Differential drinking following the two single-pellet reinforcers and the 4-pellet reinforcer was clearly evident at this time and remained consistent during the subsequent 17 experimental sessions. The results to be reported are based upon the data collected from the last ten experimental sessions. Sessional water intake was substantial for all subjects with a mean of 22.4, 52.5, 51.6, and 50.4 milliliters of water consumed per experimental session for subjects R-106, R-107, R-108 and R-109, respectively.

The number of licks per post-reinforcement interval was recorded daily. Assuming a constant amount of water is ingested with each lick, this measure is an index of the relative amount of water consumed during the IRI. It should be recalled that the size of the reinforcer was either 1 or 4 pellets and that they were delivered in a regular, repeating sequence: 1, 1, 4, 1, 1, 4, etc. The mean number of licks following each reinforcement is presented in Figure 1. Contrary to prediction, no difference was found in the amount of drinking following the ingestion of the two consecutive single-pellet reinforcers, t (9) = 1.87, 0.20, 0.49, and 2.03 for subjects R-106, R-107, R-108, and R-109, respectively, all p's $>$.05. For all subjects, less drinking occurred during the interval following the delivery of 4 pellets than during either interval that followed the delivery of a single pellet. Two-tailed t tests revealed a significant difference in the number of licks following the first single-pellet reinforcer of the pattern and the number of licks following the 4-pellet reinforcer, t (9) = 10.18, 4.73, 5.41, and 5.20 for subjects R-106, R-107, R-108, and R-109, respectively, all p's $<$.01. Similarly a significant difference was found between the amount of drinking during the inter-

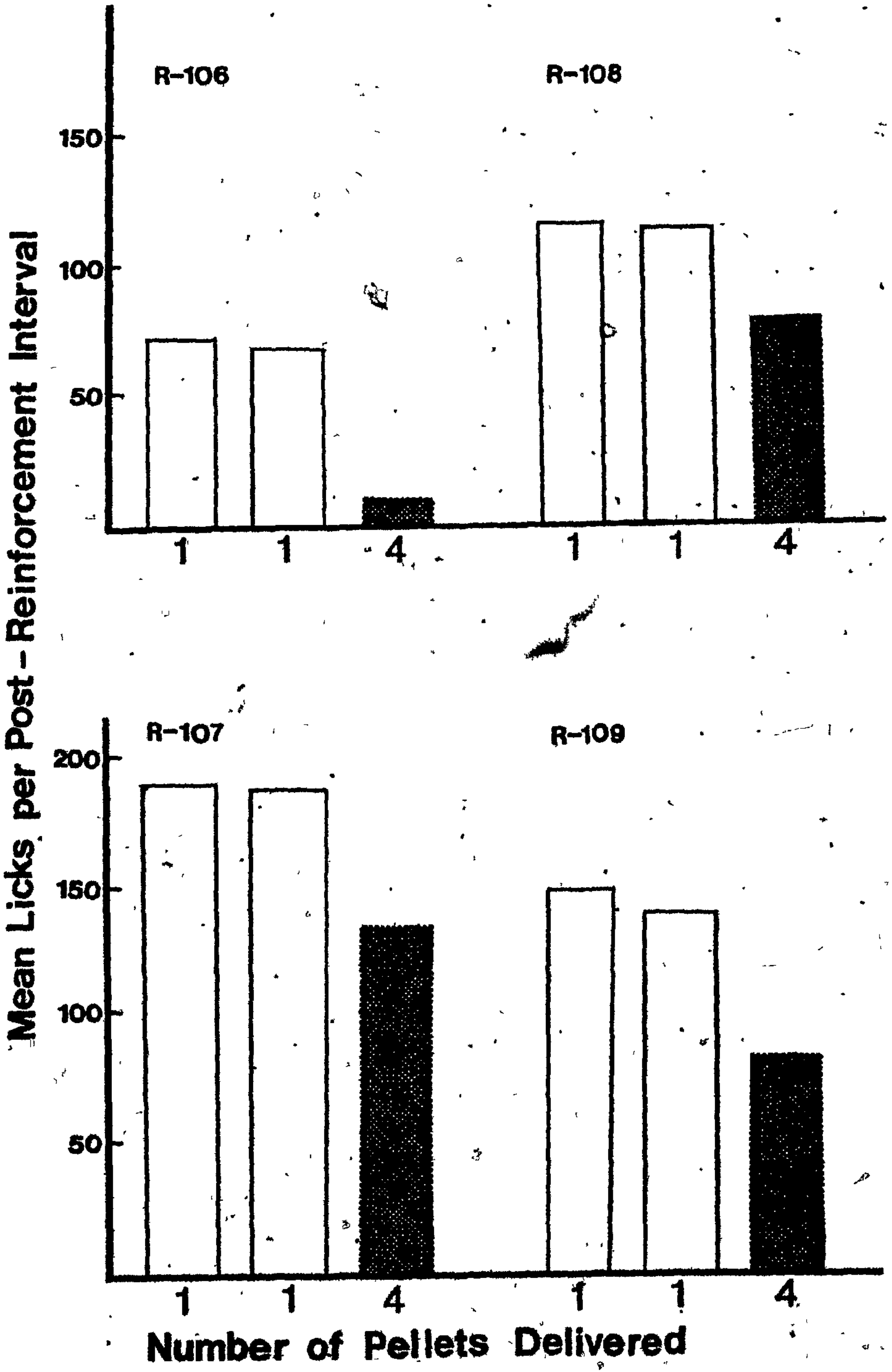
R-106
R-108
150
100
50
1
1
4
1
1
4
R-107
R-109
200
150
100
50
1
1
4
1
1
4
Mean Licks per Post - Reinforcement Interval
Number of Pellets Delivered

FIGURE 1

val preceding and succeeding the delivery of the 4 pellets, t (9) = 9.64, 6.24, 5.11, and 18.15 for subjects R-106, R-107, R-108, and R-109, respectively, all p's $<.001$.

## DISCUSSION

Two interesting findings emerged from the present experiment: 1) there was no difference in the amount of drinking after the single-pellet reinforcers and 2) less drinking followed the ingestion of the 4-pellet reinforcer.

According to the time-sharing hypothesis proposed earlier, it was expected that more drinking would occur during the interval preceding the delivery of 4 pellets than during the interval preceding the delivery of the second single-pellet reinforcer of the pattern (1, 1, 4). Contrary to this prediction, differential drinking during these two IRIs was not observed. These results therefore tend to suggest that the size of the post-prandial drink is not a function of the quantity of food to be delivered next. It should be recalled, however, that this prediction rested upon the assumption that the order in which the 1 and 4-pellet food deliveries were to occur was known to the subject. In this experiment no measure was taken that would indicate that the subject had learned the reinforcer pattern and could predict the delivery of the 4-pellet reinforcer. It is possible then that the subjects may not have discriminated between the two IRIs in question.

A stimulus change (e.g., addition of a light or tone) interpolated within one of the two intervals might serve to explicitly differentiate them. While there is much literature documenting the rat's ability to perform visual and auditory discriminations, most of this research has used a standard discrimination paradigm where learning and attending to the discriminative stimuli are advantageous to the subject. In contrast, the addition of a discriminative stimulus in the present experiment would have no functional value to the subject and as a consequence, there is a possibility that the subject would not attend to this stimulus change.

In any case, introducing a bar-pressing contingency for food would provide a means of determining whether the pattern of reinforcers had been learned. Differential rates of bar-pressing, with relatively higher rates associated with the IRI preceding the delivery of 4 pellets would imply that the sequence of reinforcers had been learned. Operant responding for food, then, would be an index of pattern learning that is independent of the drinking response. This was not done in the present experiment because the expectation was that inter-reinforcement drinking would be a function of the upcoming reinforcer and hence, the relative number of licks per interval would indicate that the pattern had been learned.

The second interesting finding that less drinking occurred following the ingestion of the 4-pellet food delivery is contrary to observations made by previous investigators (e.g., Flory, 1971; Bond, 1973; Couch, 1974). This literature suggests that as the size of the reinforcer increases, the amount of post-prandial drinking also increases. It is possible that less drinking following ingestion of the larger quantity of food in the present study was peculiar to the fixed order in which the reinforcers were delivered (1, 1, 4). In order to explore this possibility, a second study was conducted in which a similiar number of 1- and 4-pellet reinforcers were delivered per session on an FT-2 minute schedule but they occurred in a random order rather than in a repeating pattern. If, as in the first experiment, more drinking is observed following the ingestion of a single pellet, it would suggest that this finding is a consequence of within-session manipulation of reinforcer size rather than a finding specific to the fixed pattern and moreover, that the size of the post-prandial drink is not a function of the upcoming reinforcer because, in this case, the size of the next food presentation is not predictable.

## EXPERIMENT 1B

In Experiment 1B, the relative probabilities of 1- and 4-pellet reinforcer deliveries were matched with those in Experiment 1A. All experimental conditions remained the same except that the order in which 1- and 4-pellet food presentations occurred was semi-random. The purpose of this experiment was to determine if less drinking would follow the ingestion of a 4-pellet reinforcer when the size of the next expected food delivery was not predictable.

### METHOD

#### Subjects

Four experimentally naive male Long Evans hooded rats, weighing 375-400 g, were used as Ss. Each S was individually housed with water continuously available. The Ss were reduced to 80% of their free-feeding weights and were maintained at this weight throughout the course of the experiment by portions of Purina Lab Chow given in the home cage to supplement sessional food intake.

#### Apparatus

Same as in Experiment 1A.

#### Procedure

This procedure was similar to that of Experiment 1A except that the presentation of 1- and 4-pellets did not occur in a regular sequence. Instead the marginal probabilities of 1- and 4-pellet reinforcers were matched with those of the previous experiment such that p (1-pellet reinforcer) = 2/3 and p (4-pellet reinforcer) = 1/3. The relative frequencies of 1- and 4-pellet reinforcers on a given day were rarely 2/3 and 1/3, respectively. However, for each S, the mean relative frequencies did approximate the desired probabilities. No attempt was made to control the conditional probabilities as this would have resulted in sequences very similar to the 1-1-4 patterned sequence.

Following three days of magazine training, the Ss were given three one-hour sessions on consecutive days with an FT-2 minute schedule of reinforcement for food in effect. Thereafter, all sessions were 2.5 hours in length, terminating after 75 reinforcers had been delivered. As in Experiment 1A, the beginning and end of the session were signalled by the onset and offset of the houselight.

Sessional water intake and licks per post-reinforcement interval was recorded daily. In addition, drinking rate (licks per minute) was calculated for every 12-second period throughout each 2-minute inter-reinforcement interval.

## RESULTS

The mean of the observed relative frequencies of 1- and 4-pellet reinforcements for the last 10 days of experimentation were 0.66 and 0.34, respectively, approximating the desired marginal probabilities. The means of the sessional water intakes for subjects R-206, R-207, R-208, and R-209 were 29.4, 43.3, 23.1, and 31.0 milliliters, respectively. In general, sessional drinking was less than that observed in Experiment 1A.

The mean number of licks following the ingestion of a single pellet was 151.88; a mean of 38.32 licks per interval followed the ingestion of 4 pellets. The mean number of licks per post-reinforcement interval for each subject is presented in Figure 2. For all subjects, less drinking followed the ingestion of 4 pellets than followed ingestion of a single pellet. Two-tailed t tests revealed this difference to be significant, t (9) = 14.39, 5.66, 18.34, and 18.96, for subjects R-206, R-207, R-208, and R-209, respectively, all p's < .001.

Differences in the temporal topography of the drinking following 1- and 4-pellet reinforcers were also examined. Each two-minute inter-reinforcement interval was divided into 10 equal portions of 12 seconds duration. The number of licks during each of these 10 portions of the IRI following the delivery of both 1- and 4-pellet reinforcers was recorded. Based upon these data, a more general measure, drinking rate (number of licks per minute) was calculated. This measure differs from the actual number of licks recorded by a constant multiplicative factor. Figure 3 illustrates the rate of drinking during each of the

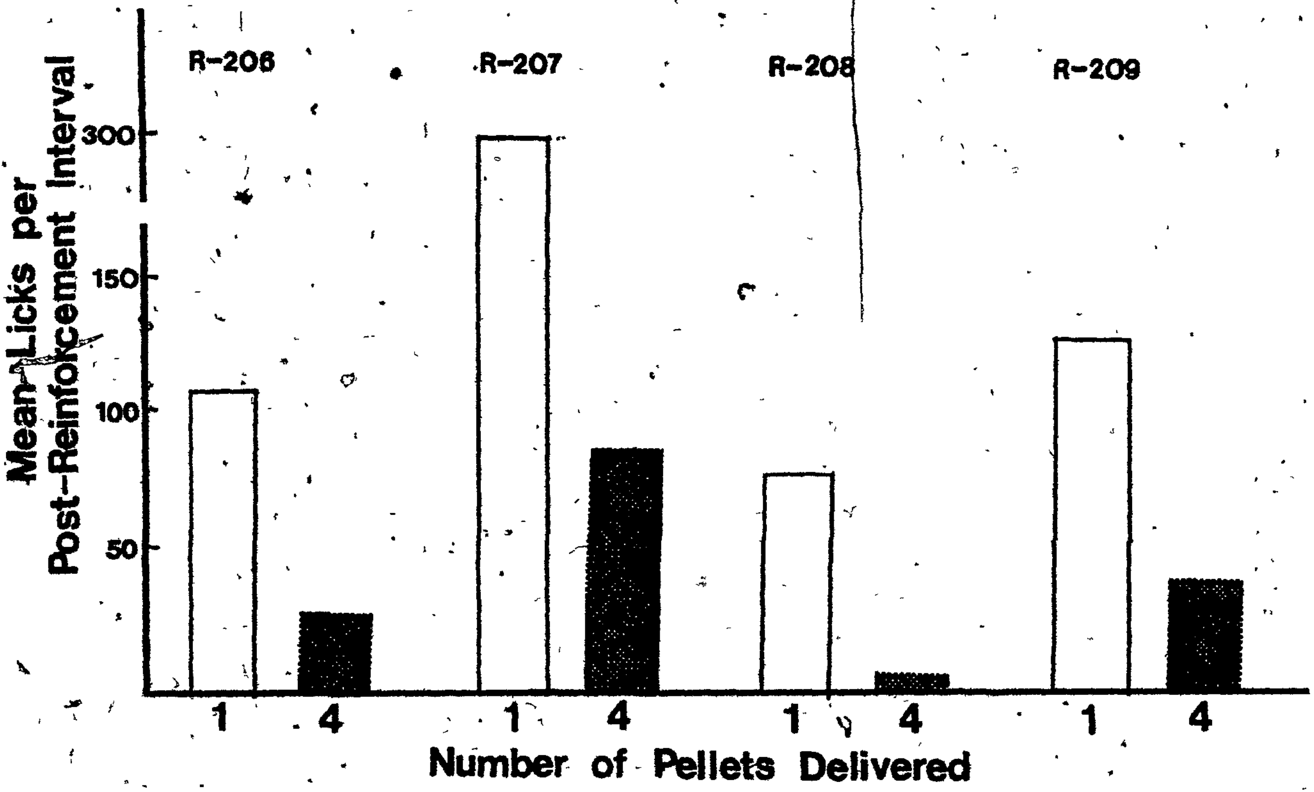
Mean Licks per Post-Reinforcement Interval
300
150
100
50
R-206
R-207
R-208
R-209
1
4
1
4
1
4
1
4
Number of Pellets Delivered

FIGURE 2

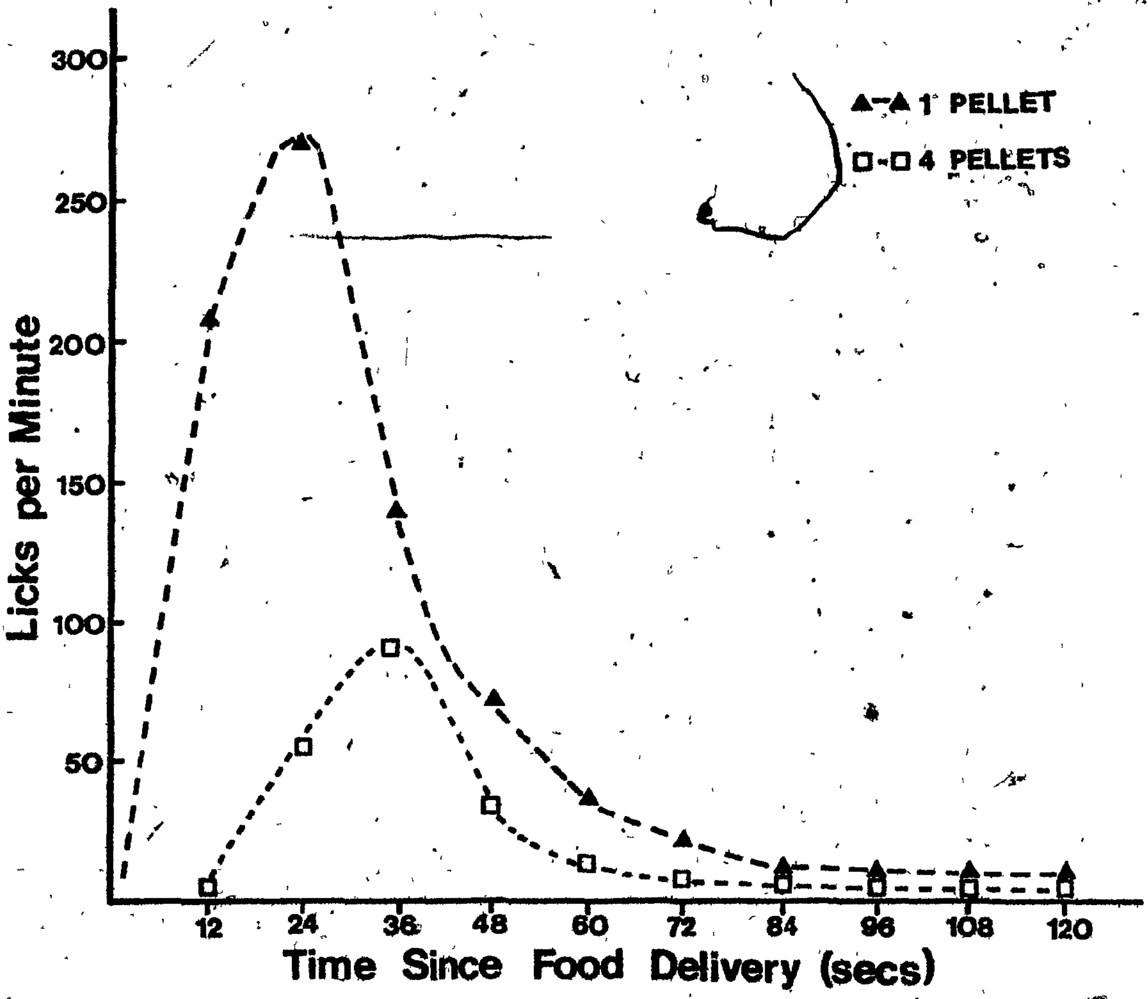
Licks per Minute
300
250
200
150
100
50
12
24
36
48
60
72
84
96
108
120
Time Since Food Delivery (secs)
▲-▲ 1 PELLET
□-□ 4 PELLETS

FIGURE 3

12-second portions of the intervals following the ingestion of 1 and 4 pellets.

Maximum drinking following the ingestion of a single pellet occurred during the second tenth of the interval; in contrast, the maximum rate of drinking following ingestion of 4 pellets was displaced, occurring during the third tenth of the interval. It was observed that regardless of the size of the reinforcer, drinking most often began immediately upon ingestion. The difference in temporal locus of the maximum rate of drinking after 1 and 4 pellets may be attributable to the fact that more time is required to ingest 4 pellets.

The shape of the intra-interval licking distribution does not appear to be different when different quantities of food are delivered. Following the ingestion of both 1 and 4 pellets, the rate of drinking increases rapidly to a maximum, followed by a slower return to asymptote at zero. For both distributions, more than 90% of total drinking occurred during the first half of the IRI. The only major difference was that for all 12-second periods of the IRI, less drinking occurred succeeding the delivery and ingestion of 4 pellets.

## DISCUSSION

The results of Experiment 1B are consistent with those of the previous experiment. When food deliveries consisting of either 1 or 4 pellets occur intermittently in a random order, less drinking follows the ingestion of the larger reinforcer. Since the magnitude of the reinforcer to be delivered was unpredictable, the results of this experiment confirm that the amount of food just ingested is the crucial determinant of the size of the post-prandial drink, de-emphasizing the amount of food expected upon the next scheduled reinforcement.

The time course of drinking within the IRI is not unlike that observed by previous investigators (e.g., Schaeffer and Salzberg, 1973). Moreover, the temporal topography of post-prandial drinking appears to be independent of the quantity of food delivered; following ingestion, there is profuse drinking which is confined to the initial portion of the IRI, terminating well before the interval has elapsed.

## GENERAL DISCUSSION

Previous investigators (Flory, 1971; Bond, 1973; Couch, 1974) found that when the number of pellets per food delivery is varied between sessions, a positive linear function relates the quantity of food ingested to the size of the post-prandial drink. The generality of this positive relationship is questioned by the present finding that the ingestion of four pellets is followed by less drinking than the ingestion of a single pellet. The reason for this discrepancy may lie in the fact that in the earlier experiments the quantity of food delivered upon each scheduled reinforcement increased between sessions, while in both of the present experiments the magnitude of the food deliveries was varied within-each session. It is possible that experience with both 1- and 4-pellet food presentations within each session may affect the motivation to drink following the ingestion of large and small quantities of food differently than when a fixed amount of food is delivered upon each scheduled reinforcement. A parametric study, varying both the amount of food delivered and the relative probability, remains to be done.

The prediction from the frustration hypothesis to be tested was that greater drinking would be observed during the IRI preceding the larger expected food delivery than during the IRI preceding the smaller expected food delivery. The results of

Experiment 1A failed to confirm this prediction; thus they seem to invalidate the frustration hypothesis. However, this experiment was predicated on the assumption that the rats had learned the order in which 1- and 4-pellet food presentations were to occur. But it may be that the rats failed to learn the pattern (1, 1, 4) so that the experiment may not have provided a critical test of the hypothesis. However, it is important to note that the results of Experiment 1B show that the quantity of food to be delivered next is not an important determinant of the amount of adjunctive drinking. In this experiment, the size of the upcoming food presentation was varied in a semi-random order so that it could not be predicted; nevertheless, the rats drank less following the ingestion of the larger food presentation as did the rats in Experiment 1A. The observed differential drinking during the IRIs following 1- and 4-pellet food deliveries is thus attributable to the magnitude of the just ingested reinforcer. The frustration hypothesis as proposed, therefore, must be rejected for its basic assumption that the amount drunk is a function of the upcoming reinforcement is untenable.

What, then, is the basis of polydipsic drinking? Observations made by several investigators (e.g., Terrace, 1971; Staddon and Simmelhag, 1971; Killeen, 1975) make plausible the suggestion that, in a variety of experimental situations, two distinct classes of behavior may be observed. Responses which are observed to occur when reinforcement is remote in time, called "interim" activities (Staddon and Simmelhag, 1971), are topographically different from responses that occur when reinforcement is imminent. The latter class of behaviors is known as "terminal" responses. When the probability of reinforcement is near-zero, the probability of terminal responding is reduced, whereas the probability of interim responding is maximal. The converse is true when reinforcement is imminent. At any given point in time, then, whether interim or terminal responding occurs is a function of the relative time remaining until the next scheduled reinforcement.

Adjunctive drinking may be considered an example of interim responding. During schedules of intermittent reinforcement for food, while drinking is occurring, terminal responding to stimuli associated with food delivery is not observed. When a bar-pressing contingency for food is in effect, drinking may result in postponing the resumption of bar-pressing after reinforcement to the latter portion of the IRI (see Segal and Bandt, 1966). Similarly, during response-independent schedules, orientation towards the food magazine and other responses in preparation for food presentation may be delayed. In all these cases, responding related to food delivery is not observed until a time when the probability of reinforcement is greater than it is immediately following the delivery of food. This observation should not be construed as fortuitous--rather a functional basis for this pattern of responding should be sought. There must be some basis for the differences in the rat's behavior when reinforcement is remote in time and the behavior observed when reinforcement is imminent. The spatio-temporal relationship between various stimuli in the experimental chamber and the delivery of the reinforcing stimulus as well as the temporal contingencies in effect are undoubtedly important. The general schema of behavior study proposed by Bindra (1974, 1976) provides a framework within which these factors may be incorporated.

After repeated training sessions in a conditioning chamber, particular situational stimuli, initially neutral, may acquire conditioned incentive values depending upon their spatial and temporal relationships to the unconditioned reinforcer (Bindra, 1974; 1976). Various features of the experimental chamber may result in gradients of incentive value defined by stimuli differing in valence; the valence of any particular stimulus may be positive or negative <u>relative</u> to other stimuli in the conditioning chamber. These relative valences need not be constant throughout the session and probably fluctuate according to the temporal contingencies in effect at a given moment. For example, when reinforcement is likely, the momentary conditioned incentive value of food-associated stimuli may be relatively greater than that of other stimuli in the test chamber. Conversely when the probability of reinforcement is near-zero, these same food-associated stimuli may have a relatively lower valence than stimuli more distant from the site of food delivery, or at least, food-associated stimuli at this time may be less positive than immediately preceding reinforcement. The behavior of the subjects at any given point in time is, therefore, postulated to be the product of the momentary conditioned incentive value of particular environmental stimuli as determined by the temporal contingency in effect.

This framework may be applied to adjunctive drinking as follows. At any given time during the IRI, the subject will respond to the conditioned incentive stimulus with the highest valence at that moment. Following the delivery and ingestion of a reinforcer, food-associated stimuli are relatively low in valence, because of the temporal remoteness of the next food delivery. Activity is therefore directed towards other situational stimuli which at this time have a greater valence. If water is available, drinking typically occurs, presumably due to the high valence of water at this time. As time elapses since the preceding reinforcement, food-associated stimuli become relatively more positive; the subject now attends to these stimuli (that is, terminal responding is observed) and drinking ceases. In other words, responding is allocated according to the momentary conditioned incentive value of particular situational stimuli.

In order to account for the present results that less drinking follows the ingestion of 4 pellets when both 1- and 4-pellet food presentations occur within a single experimental session, one would have to assume that the relative decrease in the conditioned incentive value of food-associated stimuli following reinforcement is less when that food delivery consists of 4 pellets.

Schedules of intermittent reinforcement which result in adjunctive behaviors are not unlike standard discrimination tasks in that there is a well-defined, predictable period during which reinforcement is unavailable. In discrimination tasks, the onset of some exteroceptive stimulus (e.g., light or tone) signifies the start of the S- period, and for the duration of that stimulus reinforcement is unavailable. During interval schedules of reinforcement, the period of non-reinforcement may be less discriminable; following the delivery of a reinforcing stimulus, there is an unsignalled period during which further reinforcement is improbable.

Upon the onset of S- in discrimination tasks, wing-flapping in pigeons has been observed (Terrace, 1971). The patterning of this responding has yet to be examined in any systematic, detailed manner. However, a comparison of this behavior, as well as other behaviors which occur during periods of nonreinforcement in a variety of experimental paradigms, is warranted. It would be interesting then to see how the account of adjunctive drinking in terms of the conditioned incentive value of particular situational stimuli applies to adjunctive behaviors other than schedule-induced polydipsia.

# REFERENCES

Amsel, A. The role of frustrative nonreward in noncontinuous reward situations. Psychological Bulletin, 1958, 55, 102-117.

Bindra, D. A motivational view of learning, performance, and behavior modification. Psychological Review, 1974, 81, 199-213.

Bindra, D. A theory of intelligent behavior. New York: John Wiley & Sons, 1976. (in press)

Bond, N. Schedule-induced polydipsia as a function of consummatory rate. Psychological Record, 1973, 23, 377-382.

Burks, C.D. Schedule-induced polydipsia: are response-dependent schedules a limiting condition? Journal of the Experimental Analysis of Behavior, 1970, 13, 351-358.

Burks, C.D., Hitzig, E.W. and Schaeffer, R.W. Drinking response distributions associated with a 4% sucrose FFI food schedule. Psychonomic Science, 1967, 8, 13-14.

Carlisle, H.J. Fixed-ratio polydipsia: thermal effects of drinking, pausing & responding. Journal of Comparative and Physiological Psychology, 1971, 75, 10-22.

Carlisle, H.J., Shanab, M.E., and Simpson, C.W. Schedule-induced behaviors: effect of intermittent water reinforcement on food intake and body temperature. Psychonomic Science, 1972, 26, 35-36.

Chillag, D. and Mendelson, J. Schedule-induced air-licking as a function of body weight deficit in rats. Physiology and Behavior, 1971, 6, 603-605.

Clark, F.C. Some observations on the adventitious reinforcement of drinking water under food reinforcement. Journal of the Experimental Analysis of Behavior, 1962, 5, 61-63.

Cohen, I.L. The reinforcement value of schedule-induced drinking. Journal of the Experimental Analysis of Behavior, 1975, 23, 37-44.

Cohen, I.L. and Mendelson, J. Schedule-induced drinking with food, but not ICS, reinforcement. Behavioral Biology, 1974, 12, 21-29.

Couch, J.V. Reinforcement magnitude and schedule-induced polydipsia: a re-examination. Psychological Record, 1974, 24, 559-562.

Falk, J.L. Production of polydipsia in normal rats by an intermittent food schedule. Science, 1961, 133, 195-196.

Falk, J.L. Studies on schedule-induced polydipsia. In M.J. Wayner, Ed., Thirst: Proceedings of the First International Symposium on Thirst in the Regulation of Body Water. New York: Macmillan Co., 1964.

Falk, J.L. The motivational properties of schedule-induced polydipsia. Journal of the Experimental Analysis of Behavior, 1966a, 9, 19-25.

Falk, J.L. Analysis of water and NaCl solution acceptance on schedule-induced polydipsia. Journal of the Experimental Analysis of Behavior, 1966b, 9, 111-118.

Falk,, J.L. Schedule-induced polydipsia as a function of fixed interval length. Journal of the Experimental Analysis of Behavior, 1966c, 9, 37-39.

Falk, J.L. Control of 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, 269-293.

Falk, J.L. The nature and determinants of adjunctive behavior. Physiology and Behavior, 1971, 6, 577-588.

Falk, J.L., Samson, H.H. and Winger, G. Behavioral maintenance of high concentrations of blood ethanol and physical dependence in the rat. Science, 1972, 177, 811-813.

Flory, R.K. The control of schedule-induced polydipsia: frequency and magnitude of reinforcement. Learning and Motivation, 1971, 2, 215-227.

Flory, R.K. and Lickfett, G.G. Effects of lick-contingent timeout on schedule-induced polydipsia. Journal of the Experimental Analysis of Behavior, 1974, 21, 45-55.

Flory, R.K. and O'Boyle, M.K. The effect of limited water availability of schedule-induced polydipsia. Physiology and Behavior, 1972, 8, 147-149.

Freed, E.X. and Hymowitz, N. A fortuitous observation regarding "psychogenic" polydipsia. Psychological Reports, 1969, 24, 224-226.

Gentry, W.D. Fixed ratio schedule-induced agression. Journal of the Experimental Analysis of Behavior, 1968, 11, 813-817.

Gilbert, R.M. Ubiquity of schedule-induced polydipsia. Journal of the Experimental Analysis of Behavior, 1974, 21, 277-284.

Hamilton, L.W. and Flaherty, C.F. Behavioral patterns associated with water intake in normal and septal rats. Journal of Comparative and Physiological Psychology, 1971, 76, 165-174.

Hawkins, T.D., Schrot, J.F., Githens, S.H. and Everett, P.B. Schedule-induced polydipsia: an analysis of water and alcohol ingestion. In R.H. Gilbert and J.D. Keehn, Eds., Schedule effects: drugs, drinking and aggression. Toronto: University Press, 1972.

Hymowitz, N. Schedule-induced polydipsia and aggression in rats. Psychonomic Science, 1971, 23, 226-228.

Keehn, J.D. and Cototla, V.A. Predictability of schedule-induced drink durations, Psychonomic Science, 1970, 18, 297-298.

Keehn, J.D., Cototla, V.A. and Beaton, J.M. Palatability as a function in the duration and pattern of schedule-induced drinking. Psychological Record, 1970, 20, 433-442.

Killeen, P. On the temporal control of behavior. Psychological Review, 1975, 2, 89-115.

Kisseliff, H.R. Food-associated drinking in the rat. Journal of Comparative and Physiological Psychology, 1969, 67, 284-300.

Knutson, J.F. and Schrader, S.P. A concurrent assessment of schedule-induced polydipsia. Animal Learning and Behavior, 1975, 3, 16-20.

Kutscher, C.L., Stillman, R.D., and Weiss, I.P. Food-deprivation polydipsia in gerbils (Meriones unguiculatus). Physiology and Behavior, 1968, 3, 667-671.

Laties, V.G., Weiss, B., Clark, R.L. and Reynolds, M.D. Overt "mediating" behavior during temporally spaced responding. Journal of the Experimental Analysis of Behavior, 1965, 8, 107-116.

Levitsky, D. and Collier, G. Schedule-induced wheel running. Physiology and Behavior, 1968, 3, 561-563.

Lotter, E.C., Woods, S.C. and Vasselli, J.R. Schedule-induced polydipsia: an artifact. Journal of Comparative and Physiological Psychology, 1973, 3, 478-484.

Mello, N.K. A review of methods to induce alcohol addiction in animals. Pharmacology, Biochemistry and Behavior, 1973, 1, 89-101.

Mendelson, J. and Chillag, D. Schedule-induced air-licking in rats. Physiology and Behavior, 1970, 5, 535-537.

Millenson, J.R. A motivational-reinforcement theory of emotion. Studia Psychologica, 1971, 13, 222-238.

Millenson, J.R. The facts of schedule-induced polydipsia. Behavior Research, Methods and Instrumentation, 1975a, 7, 257-259.

Millenson, J.R. Personal communication, 1975b.

Millenson, J.R. System developments in the ACT language: towards machine independence. Behavior Research, Methods and Instrumentation, 1975c, 7, 165-173.

Mowrer, O.H. Learning theory and behavior. New York: John Wiley & Sons, 1960.

Palfai, T., Kutscher, C.L. and Symons, J.P. Schedule-induced polydipsia in the mouse. Physiology and Behavior, 1971, 6, 461-462.

Porter, J.H. and Kenshalo, D.R., Jr. Schedule-induced drinking following omission of reinforcement in the rhesus monkey. Physiology and Behavior, 1974, 12, 1075-1077.

Ramer, D. and Wilkie, D.M. Adjunctive behavior as a function of type of reinforcement. Paper presented at the Meeting of the Canadian Psychological Association, Quebec City, June, 1975.

Reynierse, J.H. Excessive drinking in rats as a function of the number of meals. Canadian Journal of Psychology, 1966, 20, 82-86.

Reynierse, J.H. and Spanier, D. Excessive drinking in rats' adaptation to the schedule of feeding. Psychonomic Science, 1968, 10, 95-96.

Roll, D., Schaeffer, R.W., and Smith. Effects of a CTA on schedule-induced polydipsia. Psychonomic Science, 1969, 16, 39-41.

Rosenblith, J.Z. Polydipsia induced in the rat by a second-order schedule. Journal of the Experimental Analysis of Behavior, 1970, 14, 139-144.

Schaeffer, R.W. and Diehl, J.C. Collateral water drinking in rats maintained on fixed ratio food reinforcement schedules. Psychonomic Science, 1966, 4, 257-258.

Schaeffer, R.W. and Salzberg, C.L. Licking response distributions associated with the acquisition of schedule-induced polydipsia. Psychonomic Science, 1973, 2, 205-207.

Schuster, C.R. and Woods, J.H. Schedule-induced polydipsia in the rhesus monkey. Psychological Report, 1966, 19, 823-828.

Segal, E.F. The interaction of psychogenic polydipsia with wheel running in rats. Psychonomic Science, 1969, 4, 191-144.

Segal, E.F. Induction and the provenance of operants. In R.M. Gilbert and J.R. Millenson, Eds., Reinforcement: Behavioral analyses. New York: Academic Press, 1972.

Segal, E.F. and Bandt, W.M. Influence of collateral water drinking on barpressing under complex reinforcement contingencies. Psychonomic Science, 1966, 4, 377-378.

Segal, E.F. and Deadwyler, S.A. Water drinking patterns under several dry food reinforcement schedules. Psychonomic Science, 1964, 1, 271-272.

Segal, E.F. and Deadwyler, S.A. Determinants of polydipsia: VI. Taste of the drinking solution. Psychonomic Science, 1965a, 3, 101-102.

Segal, E.F. and Deadwyler, S.A. Determinants of polydipsia in rats: II. DRL extinction. Psychonomic Science, 1965b, 2, 203-204.

Segal, E.F. and Holloway, S.M. Timing behavior in rats with water drinking as a mediator. Science, 1963, 140, 888-889.

Segal, E.F. and Oden, D.L. Schedule-induced polydipsia: effects of providing an alternate reinforced response and of introducing a lick-contingent delay in food delivery. Psychonomic Science, 1969, 15, 153-154.

Segal, E.F., Oden, D.L., and Deadwyler, S.A. Determinants of polydipsia: III. Withholding food on a free-reinforcement schedule. Psychonomic Science, 1965, 2, 205-206.

Singer, G., Wayner, M.J., Stein, J., Cimino, K., and King, K. Adjunctive behavior induced by wheel running. Physiology and Behavior, 1974, 12, 493-495.

Shanab, M.E. and Peterson, J.L. Polydipsia in the pigeon. Psychonomic Science, 1969, 15, 51-52.

Skinner, B.F. "Superstition" in the pigeon. Journal of Experimental Psychology, 1948, 38, 168-172.

Skinner, B.F. and Morse, W.H. Concurrent activity under fixed interval reinforcement. Journal of Comparative and Physiological Psychology, 1957, 50, 277-281.

Staddon, J.E.R. and Ayres, S.L. Sequential and temporal properties of behavior induced by a schedule of periodic food delivery. Behaviour, 1975, LIV, 26-49.

Staddon, J.E.R. and Simmelhag, V.L. The "superstition" experiment: a reexamination of its implications for the principle of adaptive behavior. Psychological Review, 1971, 78, 3-43.

Stein, L. Excessive drinking in the rat: superstition or thirst. Journal of Comparative and Physiological Psychology, 1964, 58, 237-242.

Stricker, E.M. and Adair, E.R. Body fluid balance, taste and postprandial factors in schedule-induced polydipsia. Journal of Comparative and Physiological Psychology, 1966, 62, 449-454.

Taylor, D.B. and Lester, D. Schedule-inducing nitrogen "drinking" in the rat. Psychonomic Science, 1969, 15, 17-18.

Teitlebaum, P. The use of operant methods in the assessment and control of motivational states. In W.K. Honig, Ed., Operant behavior: areas of research and application. New York: Appleton-Century-Crofts, 1966.

Terrace, H. By-products of discrimination learning. In G.H. Bower, Ed., The psychology of learning and motivation, vol. 5. New York: Academic Press, 1971.

Tinbergen, N. "Derived" activities; their causation, biological significance, origin and emancipation during evolution. *Quarterly Review of Biology*, 1952, *27*, 1-32.

Wayner, M.J. and Greenberg, I. Schedule dependence of schedule-induced polydipsia and lever pressing. *Physiology and Behavior*, 1973, *10*, 965-966.

Wuttke, W. and Innis, N.K. Drug effects upon behavior induced by second-order schedules of reinforcement: the relevance of ethological analyses. In R.M. Gilbert and J.D. Keehn, Eds., *Schedule effects: drugs, drinking and aggression*. Toronto: University of Toronto Press, 1972.