Schedule Induced Polydipsia: Effects of Inter-Food Interval on Access to Water as a Reinforcer

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SCHEDULE INDUCED POLYDIPSIA: EFFECTS OF INTER-FOOD INTERVAL ON ACCESS TO WATER AS A REINFORCER

by

Richard H. Weiss

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Submitted to the
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of the
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Richard H. Weiss
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bins of the fixed time (one bin equals 10% of the fixed time). Ordinates: absolute and relative frequency (percent of total) of water bar presses. The dark bars represent the percent of total responses occurring in each bin, while the light bars represent the absolute number of responses in each bin. All data portrayed represent the mean of the last five sessions at each fixed time values.

Part A: Mean and range of water reinforcers per pellet plotted as a function of the fixed-interval or fixed-time values. Part B: Absolute and relative frequency of occurrence of the number of water reinforcers following pellet delivery. The graphs depict how many times and what percent of the time zero, one, two, etc. water reinforcers followed pellet delivery. All data portrayed represent the mean of the last five sessions at each fixed-interval or fixed-time values.
Rats maintained on a food deprivation schedule ingest large amounts of water under intermittent schedules of food delivery. This excessive drinking (schedule-induced polydipsia) typically occurs after each pellet delivery and can amount to three or four times the normal 24 hour water intake (Falk, 1961a). Schedule-induced polydipsia has also been observed in the Rhesus monkey (Schuster and Woods, 1966) and the pigeon (Shanab and Peterson, 1969). However, most studies in the area of schedule-induced polydipsia have used rats as subjects.

Polydipsia is known to occur under variable-interval (VI), fixed-interval (FI), and fixed-ratio (FR) reinforcement schedules, but only when dry food pellets are used as reinforcers (Falk, 1967; Stein, 1964). The licking behavior is usually confined to the first third of the inter-food interval. The dependent variable (licks and/or water ingestion) usually increases as the inter-pellet interval (IPI) is increased, with a maximum point around an inter-food interval of 90 to 120 sec. As the IPI is increased beyond this point, total licks typically decrease linearly. Falk (1966) and Flory (1971) have both reported this bitonic function. There are a number of parameters which affect schedule-induced polydipsia. First, the size of the food portion is important. Falk (1967) found that an increase in the number of pellets delivered (from one to two) per reinforcement on a VI schedule increased the amount of drinking per reinforcement. Flory (1971) also found similar increases in water intake (induced by FI schedules) when the number of food
pellets per reinforcer was increased from one to two pellets. Second, the subjects' deprivation level affects schedule-induced polydipsia. Most previous studies have used animals which were maintained at 70% to 80% of their free-feeding body weights. In one study, the subjects' weights were increased from 80% to 90%. The water intake remained relatively unchanged, but as body weights were increased from 90% to 105%, water intake decreased systematically. Food bar presses did not decrease until the animals were at about 105% of their free-feeding weights (Falk, 1969). Third, polydipsia occurs whether food pellets are delivered on a contingent or a non-contingent schedule (Burks, 1970). However, polydipsia is influenced by whether the food schedule is contingent or non-contingent. Fixed or variable interval non-contingent food schedules produce higher rates of polydipsia as opposed to contingent food schedules using the same inter-pellet interval (Falk, 1964). Fourth, and most critical, is the length of the inter-pellet interval. As the inter-pellet interval increases, the schedule-induced drinking increases to a maximum point and then declines as the interval is lengthened, producing a bitonic function (Falk, 1966). Flory (1971) has observed a polydipsic effect with an inter-pellet interval as low as 5 sec. This increase in drinking is not due totally to the fact that the animal has a longer inter-pellet interval within which to drink water, since drinking occurs as a post-pellet phenomenon and the licks are usually temporally distributed within the first third of the inter-pellet interval.

Polydipsia does not occur when the food delivery schedule
is continuous reinforcement (CRF) or a low fixed-ratio. However, under higher fixed-ratios, the effect does appear (Falk, 1971).

Falk (1969) has found that polydipsia is more than just a "time filler" or "displacement activity." He has shown that it has motivating properties strong enough to sustain fixed-ratio behavior. Rats (which were food but not water deprived) were maintained on a concurrent VI 1 minute (food schedule) FR 2 (water). Bar pressing for water was maintained effectively at FR values of 2, 5, 10, and 20 sec.

In the following study, the length of the inter-pellet interval for food pellets was manipulated, and schedule-induced drinking was evaluated at each interval. Instead of having the more conventional free access to water situation, water was available from a dipper on a fixed-ratio 2 schedule. In other words, not only was the amount of water ingested a dependent variable, but also the operant of bar pressing for the water was measured.

The operant was introduced for the following reasons: First, the operant behavior may be a more sensitive measure of certain experimental manipulations than the consummatory (licking) behavior. Second, more descriptive data on bar pressing in this type of situation is needed in order to perform further studies in the area. This descriptive data will aid in the selection of parameters to be used in future studies.
METHOD

Subjects

The subjects were three naive male albino rats (F-2, G-4, and F-4), individually housed in a constantly illuminated temperature controlled room. They were maintained at 80% of their free-feeding body weights with post-session Purina lab chow. Standard 45 mg Noyes lab rat food pellets were used as food reinforcers. During the initial training phase, the rats were water deprived; however, during all later experimental conditions, water was freely available in the home cage.

Apparatus

Two rat chambers were used, each equipped with a pellet dispenser, a water dipper, two response levers with three cue lights located above each bar, and two house lights in the ceiling.

The interior chambers measured 27 cm wide, 36 cm long, and 19 cm high (ceiling to grid floor). The grid was located 10 cm above the litter tray. The response levers were placed 3.8 cm above the grid floor; the pellet lever was placed 2.54 cm from the right side of the box, while the water lever was placed 2.54 cm from the left side of the box. The water dipper was situated 10.2 cm to the right of the water lever, while the pellet magazine was situated 14.6 cm to the left of the food lever. The house lights were centered in the ceiling of the chamber.
All experimental conditions were scheduled with appropriate relay circuitry and the data were recorded on a digital event recorder, a cumulative recorder, running time meters, print-out counters, and digital counters.

Procedure

In order to shape bar pressing for water, the rats were temporarily water deprived. During this time they received 30 min of water per day in addition to whatever water they obtained during their daily 45 min training session. Water reinforcers consisted of .3 ml of water per 3.5 sec dipper presentation. Once they began to bar press on a CRF schedule for water, the response requirement was increased to FR 2. They continued on this schedule for four days after which water was again made freely available in their home cages.

Once bar pressing for water was acquired, F-2 and G-4 were trained to bar press for food on ascending FI schedules (3, 5, 7, 15, and 30 sec). This was accomplished in one session, at the end of which they were on an FI 30 sec food schedule. The one non-contingent food delivery subject, F-4, was on a non-contingent fixed interval schedule (FT) and therefore did not have to bar press in order to receive food pellets. The pellet was automatically delivered at the end of a fixed time period. With an FT 30 sec schedule, the pellet was delivered after 30 sec at which point the timer was reset and another 30 sec time period began.

During the experiment, all animals were on a concurrent FI
or FT schedule for food, and FR 2 for water. Each daily session was terminated by the delivery of the fiftieth food pellet.

The following inter-pellet interval schedules were used for all the animals: FI or FT 30, 60, 80, 120, and 240 sec. During these schedules the FR 2 water schedule was always functional and the animals could obtain multiple water reinforcements during inter-pellet intervals.

Daily sessions were conducted at a particular inter-pellet interval value until a stability criterion with respect to water bar presses was attained. The criterion was that for ten consecutive experimental sessions, the mean of the first five and last five days (total session water bar presses) did not deviate more than 10% from the total mean (ten day total session water bar presses). Once the stability criterion was attained, the animals were shifted to the next inter-pellet interval.
RESULTS

One of the methods of data collection was that of recording total session bar presses separately for both the food and water bars. The inter-pellet interval distribution for both of these responses was also recorded. Each of the inter-pellet intervals studied was divided into ten equal bins. Responses falling in each of these bins were separately recorded. A print-out counter was also used to record the number of water reinforcers earned per each pellet delivery.

Figures 1 and 2 present the mean number of total session water and food bar presses for the last five sessions at each inter-pellet interval. The range of these bar presses is also shown as well as the distribution of responses within the inter-pellet interval for the two contingent food delivery animals, F-2 and G-4.

With subject F-2, as the FI increased from 30 to 60 sec, no increase in session water responding occurred. As the inter-pellet interval was further increased, small decrements in responding occurred. The maximum number of water responses occurred at intervals of 30 sec and 60 sec, but no bitonic function was observed. A similar pattern was seen with G-4 except that there was a large decrease in water responses at the 240 sec inter-pellet interval. Again no bitonic function was observed.

From 65% – 98% of the water responses for both response contingent animals were distributed within the first 30% of the inter-
FIGURE 1

Part A: Left graph – mean and range of total session water bar presses plotted as a function of fixed-interval value (sec). Right graph – mean and range of total session food bar presses plotted as a function of fixed-interval value (sec).

Part B: Left graphs – absolute and relative frequency of water bar presses falling within the successive bins of the fixed interval (one bin equals 10% of the fixed interval). Ordinates: absolute and relative frequency (percent of total) of water bar presses. The dark bars represent the percent of total responses occurring in each bin, while the light bars represent the absolute number of responses in each bin. The right graphs contain the same information except with relation to food bar presses. All data portrayed represent the mean of the last five sessions at each fixed interval value.
FIGURE 2

Part A: Left graph - mean and range of total session water bar presses plotted as a function of fixed-interval value (sec). Right graph - mean and range of total session food bar presses plotted as a function of fixed-interval value (sec).

Part B: Left graphs - absolute and relative frequency of water bar presses falling within the successive bins of the fixed interval (one bin equals 10% of the fixed interval). Ordinates: absolute and relative frequency (percent of total) of water bar presses. The dark bars represent the percent of total responses occurring in each bin, while the light bars represent the absolute number of responses in each bin. The right graphs contain the same information except with relation to food bar presses. All data portrayed represent the mean of the last five sessions at each fixed interval value.
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PERCENT OF TOTAL WATER RESPONSES

TOTAL WATER RESPONSES

TOTAL FOOD RESPONSES

PERCENT OF TOTAL FOOD RESPONSES

PART A

PART B

G-4 CONTINGENT FL FR-2
pellet interval at each of the interval values studied. This post-pellet drinking behavior was distributed such that as the FI value increased, a greater percentage of the water responses fell within the first 30% of the IPI. However, at FI 240 sec, the percent of post-food water responses decreased with subject G-4.

A monotonic increase in food bar presses occurred for F-2 as the IPI was increased. The distribution of responses showed the typical FI "scallop" effect with most responses occurring just prior to pellet delivery. The relative frequency distribution for food responses did not show much change as the IPI was increased. Approximately the same percentage of responses occurred in each bin as the IPI increased. Subject G-4 showed an increase in food responses at 60 sec, a decrease at 90 sec, and further increases up to 240 sec. However, the percentage of responses distributed in each bin remained about the same as the IPI increased.

The total session water bar press data for the non-contingent food delivery animal (F-4) were much different from that of the contingent food delivery animals. A bitonic function between total session water bar presses and the IPI was observed with a maximum value occurring at FT 90 sec (see figure 3).

Unlike the other animals, F-4's responding was not always post-pellet, since the distribution of responses shifted toward the latter portion of the IPI as the inter-pellet interval increased. At inter-pellet intervals of 30, 60, and 90 sec, from 43% - 68% of the water responses occurred during the first 30% of the inter-pellet interval. As the IPI was increased to 120 sec, the responses
FIGURE 3

Part A: Mean and range of total session water bar presses plotted as a function of value (sec).

Part B: Absolute and relative frequency of water bar presses falling within the successive bins of the fixed time (one bin equals 10% of the fixed time). Ordinates: absolute and relative frequency (percent of total) of water bar presses. The dark bars represent the percent of total responses occurring in each bin, while the light bars represent the absolute number of responses in each bin. All data portrayed represent the mean of the last five sessions at each fixed time values.
PART A

TOTAL WATER RESPONSES

30 60 90 120 240
FIXED TIME VALUE (SEC)

PART B

FT 30

FT 60

FT 90

FT 120

FT 240

BINS

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occurred mainly in the middle of the interval and at 240 sec, most of the responses were distributed towards the end of the IPI. This pattern of responding is similar to that observed for the food reinforced responding by the contingent subjects and might be attributed to adventitious reinforcement of water lever presses by the food pellet.

More comprehensive data are presented in figure 4, in that the mean number of pellets followed by various numbers (0, 1, 2, etc.) of water reinforcers can be observed. The mean number of water reinforcers and range of values for each animal can be seen in the upper graphs. At a 30 sec IPI, 50% of the pellets for subject F-2 were followed by two water reinforcers. As the IPI was increased, a greater percentage of pellets were followed by only one water reinforcer and this trend continued until at 240 sec, most pellets were followed by zero or one water reinforcer.

Table 1 depicts the percent of pellets followed by at least one water reinforcer. With all subjects there was a systematic increase in percent of pellets followed by at least one water reinforcer between inter-pellet intervals of 30 sec and 90 sec. A slight decrease was observed between 90 sec and 120 sec (still an increase from 30 sec) and a large decrease was seen with G-4 and F-4 at 240 sec. Subject F-2 showed a slight increase at the 240 sec IPI.
FIGURE 4

Part A: Mean and range of water reinforcers per pellet plotted as a function of the fixed-interval or fixed-time values.

Part B: Absolute and relative frequency of occurrence of the number of water reinforcers following pellet delivery. The graphs depict how many times and what percent of the time zero, one, two, etc. water reinforcers followed pellet delivery. All data portrayed represent the mean of the last five sessions at each fixed-interval or fixed-time values.
TABLE 1

Percent of Pellets Followed by at Least One Water Reinforcement

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<tr>
<td></td>
<td>F-2</td>
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<tr>
<td>30 sec</td>
<td>81</td>
</tr>
<tr>
<td>60 sec</td>
<td>91</td>
</tr>
<tr>
<td>90 sec</td>
<td>98</td>
</tr>
<tr>
<td>120 sec</td>
<td>98</td>
</tr>
<tr>
<td>240 sec</td>
<td>98</td>
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DISCUSSION

Schedule-induced polydipsia develops not only when water is freely available concurrently with an intermittent food delivery schedule, but also under schedules when water is concurrently available only in .3 ml portions following completion of an FR contingency. This study replicates Falk's (1966) findings in that polydipsia does have motivating properties strong enough to sustain other operant behavior.

The two contingent food delivery animals (F-2 and G-4) developed a typical polydipsic post-pellet drinking pattern. However, as the IPI was increased, the water bar presses did not show a bitonic function. The non-contingent food delivery animal (F-4) did show a bitonic function as the IPI was increased. Unlike the other animals, the drinking pattern for this subject shifted from post-pellet to pre-pellet. Perhaps the behavior shifted to an operant pattern because there was no competition with food responses (non-contingent food delivery), and as the distribution began to spread out, water bar presses were adventitiously reinforced by pellet delivery. However, the notion of a lack of competition with food responses seems to be untenable since as the IPI increased (with the contingent food delivery animals), the food and water responses were further separated within the IPI. That is, there was more time between the end of the water responses and the beginning of food responses. There is obvious incompatibility between the food and water responses.
However, it does not seem that the incompatibility accounts for the fact that water responses, with the contingent food delivery animals, occurred as a post-pellet phenomenon. If the incompatibility did account for this, it does not seem that the time between termination and onset of the two response classes would be lengthened (as it was), but rather would shorten or at least remain the same as the FI 30 sec distribution. Segal (1969) also reported a polydipsic drinking pattern evolving into an operant pattern and attributed this to adventitious reinforcement by food pellet delivery.

Subject F-2 showed a drinking pattern becoming more and more post-pellet as the IPI was increased. However, there was very little difference in the number of water bar presses recorded at each inter-pellet interval. Careful inspection of figure 1 revealed that there was no shift at all in the absolute distribution of responses as the IPI increased. At 240 sec, one bin equals 24 sec; at 120 sec, 2 bins equal 24 sec. Therefore, if the percentage of water responses within the first 24 sec is analyzed as a function of the length of the IPI, no difference is detected. At FI 60 sec, 98% of the water bar presses occurred within the first 24 sec of the interval. This percentage varied between 95% and 98% for all the other inter-pellet intervals. A similar result was analyzed in figure 2 for the contingent food delivery animal, G-4. The only discrepancy was that at 240 sec, the percentage dropped to 47%, but at all other inter-pellet intervals, the percentage was approximately 98%. Therefore, not only did no bitonic function occur, but also no systematic change in the absolute distribution of
water responses occurred.

Perhaps bar pressing (operant response) is less sensitive to schedule manipulations than is the consummatory response. This may account for the difference between the data in the present study and that of Falk (1966) and Flory (1971). This difference might also be due to the fact that Falk and Flory used many more pellets (180) which would lead to much longer sessions, but this would seem highly unlikely.

A bitonic function may have resulted if, in addition to the inter-pellet intervals used in this study, shorter and longer ones were included. This probably would have led to a more spread out bitonic function, but this is only speculative.

Table 1 shows that with G-4 and F-4, as the inter-pellet interval was increased, the percent of pellets followed by at least one water reinforcer increased to 90 sec and then decreased linearly to 240 sec. Segal, Oden and Deadwyler (1965) found this using an FI schedule of reinforcement. Their data were similar to the data recorded with F-4 in that an operant drinking pattern was observed. As the IPI increased in their study, the percent of pellets followed by water reinforcers increased to a maximum point and then decreased.

Although the data from this study do not exactly correspond to the data from other studies analyzing polydipsia as a function of the size of the inter-pellet interval, ample quantitative data was presented to support the conclusion that polydipsia does have motivational properties. A major shortcoming of many other experimental studies in this area is the failure to report sufficient
quantitative data. Studies can be legitimately compared only if such data are presented. Most studies in the area of polydipsia present only water consumption data as a function of the IPI and do not present sufficient data on the distribution of the consummatory responses. Total session data from other studies can be compared to this study. But are the distribution effects found in this study a function of an operant being introduced, discrete amounts of water being available, or are the data the same as the data in studies where water is freely available in the chamber? Comparison and replication of studies is very difficult since the lack of presentation of the quantitative data makes it very unclear concerning the similarities and differences in results of various manipulations.
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