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Acquisition of schedule-induced polydipsia by rats in proximity to upcoming food delivery

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Food-deprived rats that receive intermittent delivery of small amounts of food develop excessive drinking—specifically, schedule-induced polydipsia (SIP). A main characteristic of SIP is its occurrence at the beginning of interfood intervals. The purpose of this study was to demonstrate that SIP can be developed toward the end of interfood intervals, in closer proximity to upcoming than to preceding food delivery. In Experiment 1, two groups were exposed to a fixed-time (FT) 30-sec food schedule with water available during the first or the last 15 sec of each interfood interval. Two additional groups, which had access to water throughout, were exposed to FT 30-sec or FT 15-sec schedules of food presentation. The FT 30-sec group with free access to water developed the highest level of intake; similar and intermediate levels were induced in all the remaining groups. In Experiment 2, three groups of rats were exposed to an FT 90-sec food schedule with water available during the first, the second, or the last 30 sec of each interfood interval. One additional group with access to water throughout was exposed to the FT 90-sec schedule of food presentation. The group with free access to water developed a higher level of consumption than did the other groups, but by the end of training none of the four groups showed statistical differences in polydipsic drinking. Results show that adjunctive drinking can be developed in proximity to upcoming food delivery even with long interfood intervals.

Food-deprived rats exposed to an intermittent food reinforcement schedule typically drink small quantities of water after each food pellet is delivered. Because rats end up drinking large amounts of water over the entire experimental session, this behavior has been termed *schedule-induced polydipsia* (SIP; Falk, 1961). It has been suggested that SIP is the prototype of a class of behavior known as *adjunctive behavior*. A main characteristic of adjunctive behavior is its occurrence at higher rates at the beginning of interreinforcement intervals than in baseline periods (Falk, 1971).

Several studies have been conducted to investigate whether SIP could be developed at times other than the beginning of interreinforcement intervals. For example, after stable water intake was obtained, Flory and O'Boyle (1972) prevented drinking by rats during 15-sec portions of a fixed-interval (FI) 1-min food reinforcement schedule. They found that the amount of drinking was affected only slightly by this procedure even when drinking was not possible for the 15 sec that followed food delivery. After a 15-day period of SIP acquisition, Gilbert (1974) divided 60- or 210-sec interfood intervals into six parts, in such a manner that water was available for a random period of 10 or 35 sec during each interfood interval. He found that rats drank similar amounts of water regardless of the timing of the water accessibility period. Daniel and King (1975) exposed three groups of rats to a fixed-time (FT) 65-sec schedule of food delivery. During the first 5 sec of each interfood interval, water was not made available to any of the groups in order to allow the rats to consume the pellets. The remainder of the interval was divided into three 20-sec periods, water being available only during the first, the second, or the third 20-sec period for the three different groups. The rats in all three groups drank similar amounts of water.

The studies reviewed above seem to show the possibility of the development of SIP in periods other than the beginning of the interreinforcement interval. However, in a more recent study Avila and Bruner (1994) reported results somewhat contradictory to preceding findings. After 40 sessions in which water was continuously available, an

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FI 128-sec food reinforcement schedule was divided into 16-sec periods of water accessibility. During the first block of sessions, water was available immediately before reinforcement delivery. The period of water accessibility was moved back within the interreinforcement interval in successive blocks of sessions. Avila and Bruner found that water consumption generally decreased as the water accessibility period was separated from the time of reinforcement delivery. They concluded that SIP was not a ubiquitous phenomenon.

All of the reported studies have a number of problems that preclude any firm conclusion about the possibility that SIP would develop in portions of the interfood interval other than the postpellet period. First, the numbers of subjects employed in the experiments were very small (2 in Gilbert's [1974] study, 3 in the studies of Flory & O'Boyle [1972] and Avila & Bruner [1994], and 4 per group in the case of Daniel & King [1975]). Second, only Daniel and King studied the acquisition of SIP; all the other researchers manipulated water accessibility after SIP had developed. Third, no study informs about the exact distribution of adjunctive drinking within interfood intervals or about the persistence of drinking in each interfood interval. These characteristics are important for defining drinking as an adjunctive behavior.

The temporal distribution of SIP is very well known. Generally, rats begin drinking immediately after delivery of a pellet, and drinking peaks quickly and then decreases prior to delivery of the next pellet. This inverted U-shaped pattern is general for schedule-induced behaviors (Falk, 1961; Killeen, 1975; Roper, 1980). However, it is unknown whether this inverted U-shaped function is displayed when SIP is developed in periods other than the beginning of interfood intervals. Also, no study has been conducted to compare drinking that occurs under limited access to water with drinking that would occur if water were freely available under a schedule with an interfood interval of the same duration as the water accessibility period. In the present experiments, we incorporated procedures that overcome all of the above-mentioned difficulties, thus contributing to a better characterization of SIP acquisition in time periods closer to the upcoming food delivery than to the preceding one.

Finally, the development of SIP in the last part of the interfood interval has important implications for some of the behavioral hypotheses proposed for adjunctive behaviors. Lashley and Rosellini (1980, 1987) argued that SIP should occur solely in periods of low probability of reinforcement, such as the postpellet period. However, if SIP can be developed in portions of interfood intervals associated with high probability of reinforcement, such as the last part of the interfood interval, Lashley and Rosellini's theory cannot adequately account for the development of SIP. In contrast, alternative theories, such as the behavioral systems theory (Timberlake, 1990), which consider a motivational state of prereward search that induces high activity, can better account for the existence of a displaced SIP in the interfood interval.

EXPERIMENT 1

Experiment 1 had three specific objectives. The main objective of this experiment was to investigate whether SIP can be developed even if water is not available after the delivery of reinforcement. The second objective was to characterize the temporal distribution and persistence of this drinking within and throughout the interfood intervals. Finally, the third objective was to know if this drinking develops in an amount similar to that induced by a food schedule with the same amount of time of water accessibility but with no restriction. An FT 30-sec food delivery schedule was chosen because in previous studies it has been shown to be the schedule that induces the highest rate of SIP (Flores & Pellón, 1995, 1997). Given that drinking behavior is highly predominant during such food schedules, its temporal distribution could in principle be flexible enough to occupy any portion of the interfood intervals in which water was available.

Method

Subjects. The subjects were 38 experimentally naive male Wistar albino rats, purchased from the bioterium of the University of Granada (Spain). They were 90 days old with a mean free-feeding weight of 300 g at the beginning of the experiment. They were housed in groups of 4 in an environmentally controlled room (22ºC temperature and a 12:12-h light:dark cycle, with lights on at 8 a.m.). After a period of 10 days of habituation to the housing conditions and before training, the rats were gradually reduced by food deprivation to 85% of their free-feeding weights. They were maintained at those weights until the end of the experiment. Water was continuously available in the home cages. All animal use procedures were in accordance with Spanish Royal Decree 223/1998 pertaining to minimizing stress and discomfort in animals.

Apparatus. The experiment was conducted in six identical test chambers (MED Associates, St. Albans, VT) measuring 32 × 25 × 34 cm, with stainless steel grid floors. Each chamber was contained in a ventilated sound-attenuating cubicle with a viewing window on the right wall. The front and back panels of the test chambers were aluminium, whereas the right and left walls and the roof were transparent acrylic plastic. A pellet dispenser supplying 45-mg standard rat food pellets (Bio-Serv, Frenchtown, NJ) to a receptacle (5 × 5.5 cm) was installed behind the center of the front wall of each chamber, 2 cm from the grid floor. The back panel of each chamber had a receptacle 3.7 cm from the grid floor in which a water spout could be inserted. A movable gate controlled access to the water spout. The test chambers were illuminated by one 3-W light bulb 27 cm from the grid floor during the experimental sessions. The ventilation fan produced a background noise of 60 dB that functioned as masking sound. The scheduling and recording of experimental events were controlled by means of a personal computer programmed in MED-PC.

Procedure. *Baseline period*. When each rat had stabilized at 85% of its free-feeding weight, a water ingestion test was given on 2 successive days. The rats were placed individually in separate cages (similar to their home cages). Each of these cages contained a dish with the same amount of food to be delivered in the experimental sessions (i.e., 60 45-mg pellets). The amount of water consumed by each rat in a period of time similar to the total duration of the experimental sessions was measured. For the groups with limited access to water, the baseline was calculated for the same amount of time that the rats had access to water in the experimental sessions. This measure provided a baseline against which to assess the degree of any schedule-induced polydipsia subsequently observed in the experiment.

Magazine training. On the following day, the rats were adapted to the test chambers for 30 min and were allowed to eat 20 food pellets that had previously been placed in the food receptacles. The water spouts were not installed.

Experimental phase. The animals were divided into four groups ($n = 10$ except in Group FT 30-A, in which $n = 8$). The two experimental groups were exposed to an FT 30-sec food delivery schedule with water available only during the first or the last 15 sec of each interfood interval (Groups FT 30-A and FT 30-B, respectively). Two additional groups served as controls. They were exposed to either an FT 30-sec or an FT 15-sec food delivery schedule and had access to water throughout the entire session (Groups FT 30 and FT 15, respectively). Sessions lasted 30 min for Groups FT 30, FT 30-A, and FT 30-B and 15 min for Group FT 15. All the groups received the same amount of food in each session (60 food pellets). This training lasted 20 days. The rats in Group FT 30 were subsequently transferred, for another 20 sessions, to a schedule similar to that of Group FT 30-B, in which access to water was restricted to the last 15 sec of each interfood interval. In order to distinguish between these two treatments, the latter (with restricted access during maintenance) will be referred as *Group FT 30-M*.

The following measures were recorded for each rat in each session: (1) the total amount of water consumed, in milliliters and (2) the percentage of interfood intervals in which at least one lick occurred. During the last experimental session, we also recorded the number of licks in each of the 2-sec bins in which the interfood interval was divided.

Data analyses. The mean water consumption by each group of rats across the experimental sessions and the percentage of interfood intervals with at least one lick were analyzed by a two-factor analysis of variance (ANOVA) with a between-groups factor (group) and a within-subjects factor (sessions). Comparison of FT 30 and FT 30-M treatments was analyzed by an ANOVA with a within-subjects factor (sessions). The total number of licks per 2-sec bin for the groups with restricted access to water (Groups FT 30-A, FT 30-B, and FT 30-M) and Group FT 15 were also analyzed by a two-factor ANOVA, with a between-groups factor (group) and a within-subjects factor (bins). The FT 30 treatment was not included in this analysis because of the different numbers of bins per interfood interval. When necessary, post hoc comparisons were calculated by Newman-Keuls' test. All analyses were computed by the Statistica software package. The significance level was set at $p < .05$.

Results and Discussion

Figure 1 shows the mean water intake for all the groups during acquisition and maintenance of SIP. All the rats developed SIP after being exposed to the different FT schedules of food delivery. During the baseline period, the rats in Groups FT 30-A, FT 30-B, FT 15, and FT 30 drank an average of 3.8 ± 0.3, 2.3 ± 0.2, 3.3 ± 0.3, and 3.9 ± 0.3 mL, respectively. In the experimental phase, the maximum total amount of water was ingested by Group FT 30, with a mean intake of 26.72 ± 1.19 mL during the last 5 days of acquisition. Excessive but smaller quantities of water were also ingested by the other groups. The mean intake during the last 5 days was 20.61 ± 2.29, 20.14 ± 1.83, 19.18 ± 0.92, and 20.88 ± 1.18 mL for Treatments FT 30-A, FT 30-B, FT 15, and FT 30-M, respectively. The ANOVA showed differences that were almost statistically significant between Groups FT 30-A, FT 30-B, FT 15, and FT 30 during acquisition [$F(3,34) = 2.78$, $p = .06$]. Session effects were statistically significant [$F(19,646) = 101.65$, $p < .001$], as was the interaction between groups and sessions [$F(57,646) = 1.97$, $p < .001$]. The post hoc analyses indicated significant differences between Group FT 30 and the other three groups in sessions 16–20 ($p < .05$). Significant differences were also found between the FT 30 and FT 30-M treatments [$F(39,351) = 15.83$, $p < .001$]. The post hoc analyses indicated significant differences in the first six sessions in the sense that in Treatment FT 30-M the animals began by drinking more given that they had had previous experience with the FT 30-sec schedule ($p < .05$). There were also significant differences in the last five sessions between the Group FT 30 and FT 30-M treatments, indicating that FT 30-M had levels of water intake similar to those of the other groups having 15 sec of access to water.

Figure 2 shows the distribution of licking within interfood intervals in the last session of acquisition. The statistical analyses carried out for Groups FT 30-A, FT 30-B, FT 15, and FT 30-M did not show between-groups differences [$F(3,34) < 1$], although there was a bin factor effect [$F(7,238) = 24.88$, $p < .001$] and an interaction of group × bin [$F(21,238) = 5.41$, $p < .001$]. Post hoc analyses showed that Groups FT 15 and FT 30-A were dif-

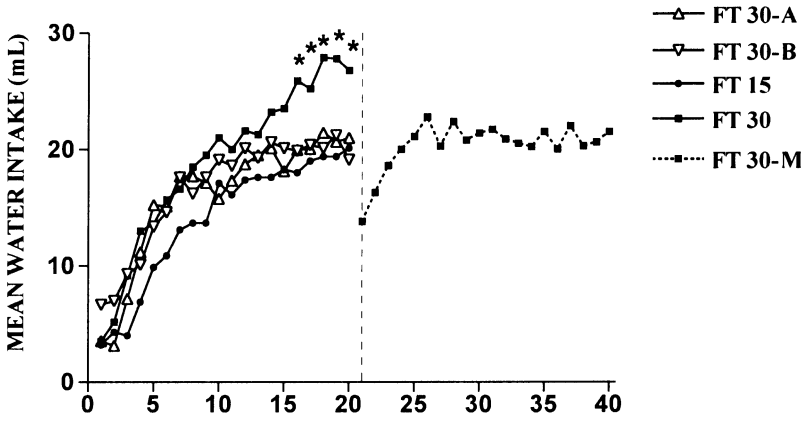

Figure 1. Mean water intake for the different groups throughout the sessions. From Session 21, Group FT 30 became Group FT 30-M (see the Procedure section of Experiment 1 for a more complete explanation). *$p < .05$.

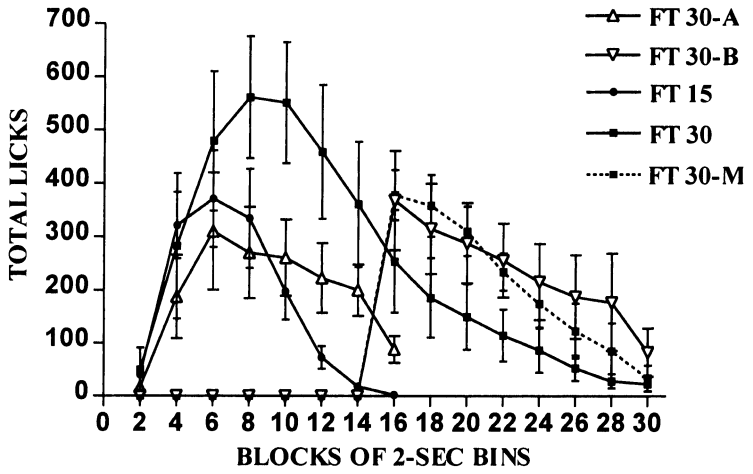

Figure 2. Distribution of licking within interfood intervals in the last session of acquisition expressed as the mean and standard error of licks occurring in each of the 2-sec bins into which the interfood intervals were divided.

ferent from Groups FT 30-B and FT 30-M in the first bin ($p < .001$), whereas no differences were found between Groups FT 15 and FT 30-A or between Groups FT 30-B and FT 30-M. This means that Groups FT 30-B and FT 30-M peaked earlier (in the first 2 sec of access to water) than Groups FT 15 and FT 30-A (which peaked in the third bin). Group FT 30 peaked in the fourth bin, quite similar to Groups FT 15 and FT 30-A.

The percentage of interfood intervals in which at least one lick occurred is shown in Figure 3. The statistical analyses for Groups FT 30-A, FT 30-B, FT 15, and FT 30 showed no between-groups differences [$F(3,34) < 1$], which means that once the rats acquired SIP they drank in all the interfood intervals regardless of whether or not they had restricted access to water. Although the session effect [$F(19,646) = 103.66$, $p < .001$] was significant, reflecting the process of acquisition, the group × session interaction [$F(57,646) < 1$] was not significant. Differences were found between the FT 30 and FT 30-M treatments [$F(39,351) = 12.29$, $p < .001$]. The post hoc analyses indicated significant differences in Sessions 1 and 2 ($p < .05$). As with water intake (see Figure 1), the rats in the FT 30-M condition began by drinking more given that they first had an experience with the FT 30-sec schedule.

EXPERIMENT 2

Experiment 1 showed that rats can develop SIP when water is available only in the second half of 30-sec interfood intervals, this being similar to the adjunctive drink-

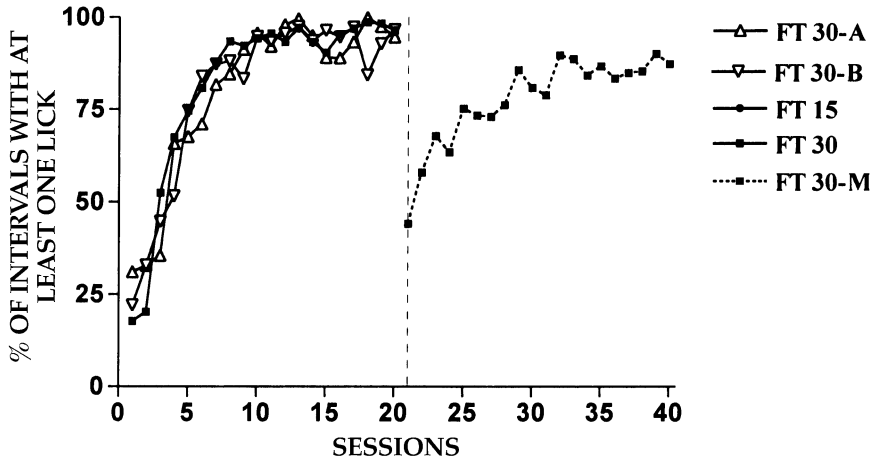

Figure 3. Mean percentage of intervals with at least one lick for the different groups throughout the sessions. From Session 21, Group FT 30 became Group FT 30-M (see the Procedure section of Experiment 1 for a more complete explanation).

ing developed by rats when water is available for 15 sec throughout the interfood interval or in the first half of the 30-sec interfood interval. A fundamental finding is that SIP shows an inverted U-shaped relationship with changes in reinforcement frequency (Falk, 1966; Flory, 1971). The highly dominant drinking induced by an FT 30-sec schedule therefore might not be representative of the adjunctive drinking produced by other schedules with longer interfood intervals. To generalize the results from the first experiment, animals in a second experiment were exposed to an FT 90-sec schedule of food presentation, a longer interfood interval that in our laboratory has been shown to induce less polydipsic drinking than an FT 30-sec schedule (Flores & Pellón, 1995). The objectives of the second experiment were to further investigate whether or not SIP can be developed in the last part of the interfood intervals when low-frequency reinforcement schedules are used and, if so, to characterize the temporal distribution and persistence of this drinking.

Method

Subjects and Apparatus. The subjects were 31 experimentally naive male Wistar albino rats of the same age and weight as those used in Experiment 1. All animal care procedures were as described in Experiment 1. The apparatus were also the same as in the previous experiment.

Procedure. *Baseline and magazine training*. These were identical to those used in Experiment 1.

Experimental phase. The animals were divided into four groups ($n = 8$ except in Group FT 90-B, in which $n = 7$). Three experimental groups were exposed to an FT 90-sec food delivery schedule with water available only during the first, second, or last 30 sec of each interfood interval (Groups FT 90-A, FT 90-B, and FT 90-C, respectively). One additional group (Group FT 90) served as a control and was exposed to an FT 90-sec food delivery schedule with access to water throughout the entire session. Sessions lasted 90 min for all the groups, and all the groups received the same amount of food in each session (60 food pellets). This training lasted 20 days. The rats in Group FT 90 were then transferred, for another 20 sessions, to a schedule similar to that of Group FT 90-C, in which access to water was restricted to the last 30 sec of each interfood interval. In order to distinguish between these two treatments, the latter (with restricted access during maintenance) will be referred to as *Group FT 90-M*.

The same measures were recorded in this experiment as in Experiment 1.

Data analyses. Data analyses were as described for Experiment 1, except that the within-subjects comparison was between the FT 90 and FT 90-M treatments. The analysis of the total number of licks per bin was for Groups FT 90-A, FT 90-B, FT 90-C, and FT 90-M; the FT 90 treatment was not included in the analysis because of the different number of bins per interfood interval.

Results and Discussion

Figure 4 shows the mean water intake for all the groups during acquisition and maintenance of SIP. All the rats developed SIP after being exposed to the different FT schedules of food delivery. During the baseline period, the rats in Groups FT 90-A, FT 90-B, FT 90-C, and FT 90 drank an average of 4.9 ± 0.5, 4.0 ± 0.3, 5.7 ± 0.7, and 5.2 ± 0.4 mL, respectively. In the experimental phase, the maximum total amount of water was ingested by Group FT 90, with a mean intake of 19.25 ± 2.96 mL during the last 5 days of acquisition. Similar but smaller quantities of water were also ingested by the other groups. The mean intake during the last 5 days was 11.80 ± 2.13, 13.12 ± 2.94, 15.29 ± 2.60, and 10.97 ± 2.23 mL for Groups FT 90-A, FT 90-B, FT 90-C, and FT 90-M, respectively. The ANOVA did not show significant group differences during acquisition [$F(3,27) = 1.9$, $p = .15$]. Session effects were statistically significant [$F(19,513) = 22.63$, $p < .001$], meaning that all the groups developed SIP, even those that had to wait for 60 sec to get access to the 30-sec drinking period. The interaction between groups and sessions was not statistically significant [$F(57,513) =$

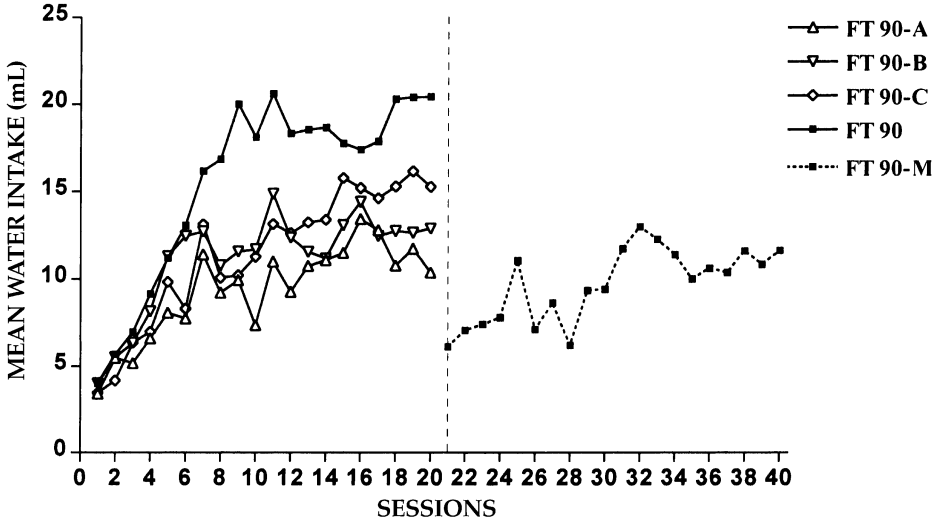

Figure 4. Mean water intake for the different groups throughout the sessions. From Session 21, Group FT 90 became Group FT 90-M (see the Procedure section of Experiment 2 for a more complete explanation).

1.22, $p = .14$], indicating that all the groups drank similar amounts of water by the end of the training. However, an analysis of the group × session interaction during just the first 10 days of acquisition, in which Group FT 90 had reached the asymptotic level, showed significant differences between Group FT 90 and the rest of the groups for Days 8, 9, and 10 [$F(27,243) = 1.64$, $p < .05$], indicating that Group FT 90 acquired SIP faster than all the other groups. At Day 20, Group FT 90 still drank more than the rest of the groups, and almost double that of Group FT 90-A. However, the variability in drinking produced by the FT 90-sec food schedule precluded statistically significant differences. Statistically significant differences were found between the FT 90 and FT 90-M treatments [$F(39,273) = 5.89$, $p < .001$]. The post hoc analyses showed significant differences in the last four sessions, indicating that under the FT 90-M condition the animals drank less than they did under the FT 90 condition, and they drank amounts similar to those of the other groups having 30 sec of access to water.

Figure 5 shows the distribution of licking within interfood intervals in the last session of acquisition. The statistical analyses carried out for Groups FT 90-A, FT 90-B, FT 90-C, and FT 90-M did not show between-groups differences [$F(3,27) < 1$], although there was a bin factor "effect [$F(14,378) = 9.95$, $p < .001$] and an interaction of group × bin [$F(42,378) = 4.16$, $p < .001$]. Post hoc analyses showed significant differences between Group FT 90-A and Groups FT 90-B, FT 90-C, and FT 90-M in the first two 2-sec bins ($p < .05$). This means that Groups FT 90-B, FT 90-C, and FT 90-M peaked earlier (around the second and third bins) than Group FT 90-A (which peaked in the ninth bin). Group FT 90 peaked in the fourth to fifth bins.

The percentage of interfood intervals in which at least one lick occurred is shown in Figure 6. The statistical analyses for Groups FT 90-A, FT 90-B, FT 90-C, and FT 90 showed no between-groups differences [$F(3,27) = 2.017$, $p = .14$], which means that once the rats had acquired SIP, they drank in around 70% of the interfood intervals regardless of whether or not they had restricted access to water. Although the session effect [$F(19,513) = 11.98$, $p < .001$] was significant, reflecting the process of acquisition, the group × session interaction [$F(57,513) < 1$] was not significant. Differences were found between the FT 90 and FT 90-M treatments [$F(39,351) = 12.29$, $p < .001$], although the post hoc analyses did not show significant differences between groups during the last five experimental sessions.

GENERAL DISCUSSION

The results of these experiments indicate that systematic and excessive drinking could be obtained in later parts of interfood intervals, thus occurring in proximity to upcoming food delivery. The form of the temporal distribution and the persistence of this drinking during interfood intervals were similar to typical SIP occurring in postpellet periods. Both conclusions are true for short and long interfood intervals.

Although SIP is considered a puzzling behavior in the field of animal learning, some explanations have been advanced. For example, Lashley and Rosellini (1980, 1987) argued that SIP should occur solely in periods of low probability of reinforcement, being not just a consequence of interruption of consumatory behavior. In our experiments, the rats developed SIP even though access to water was restricted to the last part of the interfood interval and, in

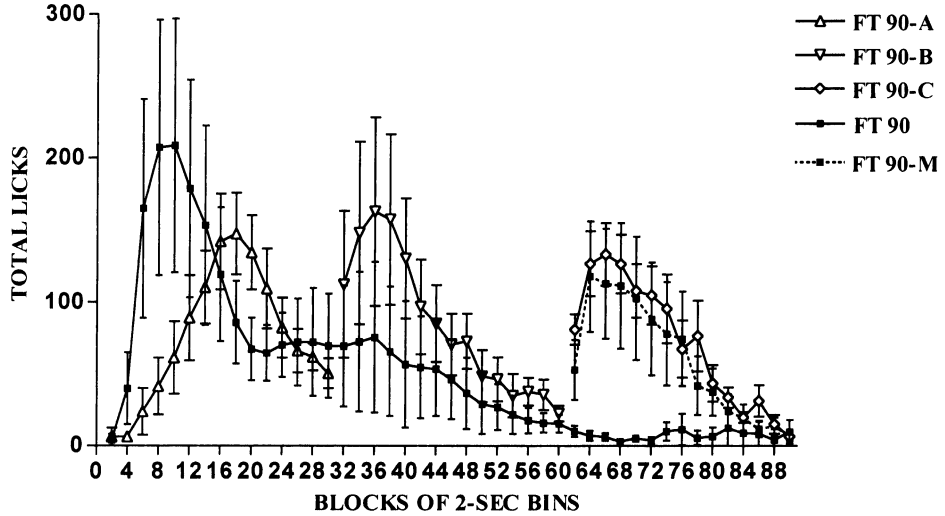

Figure 5. Distribution of licking within interfood intervals in the last session of acquisition expressed as the mean and standard error of licks occurring in each of the 2-sec bins into which the interfood intervals were divided.

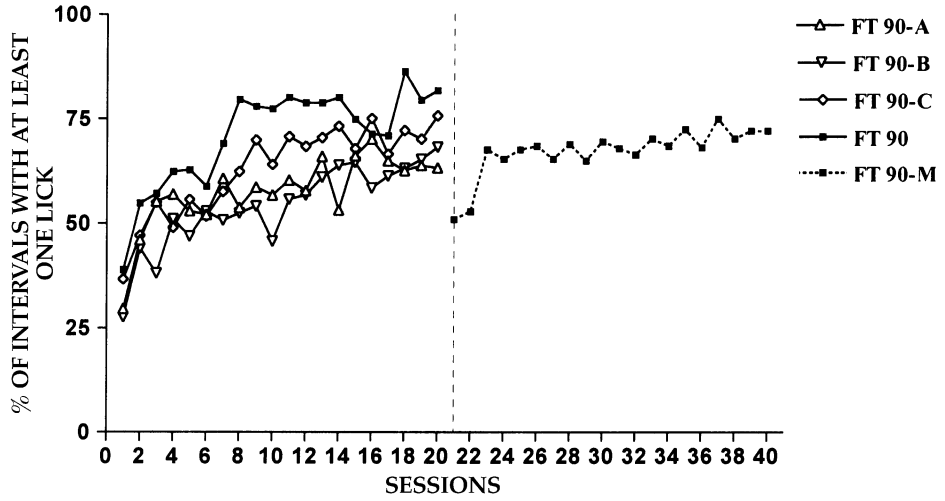

Figure 6. Mean percentage of intervals with at least one lick for the different groups throughout the sessions. From Session 21, Group FT 90 became Group FT 90-M (see the Procedure section of Experiment 2 for a more complete explanation).

agreement with some previous findings (Daniel & King, 1975; Gilbert, 1974), schedule-induced drinking could be developed in portions of the interfood interval other than those normally associated with a low probability of reinforcement (i.e., the postpellet period). Consequently, that theory cannot adequately account for the development and maintenance of SIP shown in the present study.

At first sight, this conclusion appears somewhat contrary to that of Flory and O'Boyle (1972) and Avila and Bruner (1994). Flory and O'Boyle argued that because SIP was attenuated when water was unavailable immediately after food consumption, a factor such as the low probability of reinforcement and stimuli associated with recent pellet ingestion could be influencing SIP. However, in our first experiment the rats with restricted access to water drank almost the same amount as those in unrestricted conditions with a similar time of access to water. Avila and Bruner found that water consumption was lowest when water accessibility periods were at the beginning of the interreinforcement interval and at a maximum when these periods took place immediately before pellet delivery. Given that the procedure implied that all the rats were first exposed to the period with water at the end of the interreinforcement intervals, water accessibility and reinforcement delivery may have been associated, resulting in a superstitious conditioning between these two events.

A way to characterize drinking as schedule induced is by examining whether or not it occurs in every interfood interval and whether or not it shows an inverted U-shaped distribution between successive food deliveries (Falk, 1961; Killeen, 1975). In the present experiments, at the end of training all the animals showed a robust pattern of drinking in most interfood intervals regardless of whether or not they had free access to water all the time (see Figures 3 and 6).

It is interesting to note that in Experiment 1, in which a high frequency of food presentation was scheduled, the rats drank in 100% of the interfood intervals. However, in Experiment 2, in which a lower frequency of food presentation was scheduled, the rats drank in around 70% of the interfood intervals. Thus, whether or not they had free access to water, there was a reduction in SIP as frequency of food presentation decreased. This result is in agreement with previous data in the literature (Falk, 1967; Flores & Pellón, 1995, 1997).

All the groups also showed inverted U-shaped temporal distributions of licking within interfood intervals, regardless of whether they had free access to water and regardless of the frequency of food presentation (see Figures 2 and 5). Treatments FT 30-B and FT 30-M from Experiment 1 are the only two exceptions. In these two conditions, a decreasing linear function of licks was produced with the passage of time. The reason for this different temporal distribution might be that the FT 30-sec food schedule induced very predominant drinking, so that the animals were ready to lick as soon as the water bottle was available (they had 15 sec to reach the water area). In general, drinking by the animals that had access to water in the middle or at the end of the interfood intervals peaked earlier than drinking by the animals that had access to water only at the beginning of the interfood intervals. Reaching the water area immediately after collecting a food pellet requires the time necessary to eat the pellet and move to the side of the box containing the water device (see the performance of Groups FT 30 and FT 90 in Figures 2 and 5, respectively). However, interference from eating cannot explain why the instantaneous drinking disappeared in the FT 90 later access intervals. It is interesting to note that there is a further displacement in peak as the temporal distance from the next pellet increases. When temporal distance is short

(15 sec—see Figure 2), the peak appears in the first 2 sec; with medium temporal distances (30 or 60 sec—see Figures 2 and 5) the peak appears between 4 and 8 sec, and with longer temporal distances (90 sec—see Figure 5) the peak appears between 10 and 18 sec. This result is also in agreement with previous data showing a further displacement in peak as the interpellet interval increases (Falk, 1967; Flores & Pellón, 1997; Flory, 1971; Killeen, 1975; Roper, 1980; Wetherington, 1979).

Previous reports have shown that a main variable controlling SIP is the length of the interfood interval. With our procedures, the time of access to water does not necessarily match the length of the interfood interval, thus allowing us to consider the relative importance of these two factors. In the first experiment, Groups FT 30-A, FT 30-B, and FT 30-M drank quantities of water similar to those of Group FT 15-sec but smaller than those of Group FT 30-sec. Therefore, rats appear to drink the same amount given a fixed time of access to water, but independently of the frequency of food presentations or the exact moment at which water is available. However, the rats with restricted access to water during the FT 90-sec schedules in Experiment 2 (Groups FT 90-A, FT 90-B, and FT 90-C) drank about half as much as the rats in the FT 30 condition of Experiment 1, although all had the same total availability of water. Therefore, as was suggested previously in the analysis of the percentage of intervals with at least one lick, the frequency of food presentations seems to contribute to drinking as well.

Finally, the present data are also contrary to the idea that adjunctive behaviors are stereotyped behaviors. As was also shown by Flory and O'Boyle (1972), Gilbert (1974), and Avila and Bruner (1994), Groups FT 30-M and FT 90-M show that rats that have developed a postpellet pattern of drinking can then shift the temporal location of licks in a very small number of sessions. This is an indication of behavioral flexibility.

Adjunctive behavior seems to be better characterized when one considers the normal patterns of behavior shown by animals as portrayed, for example, by theories of behavior systems (see Timberlake, 1994). Drinking and eating usually occur together in mammals, and despite the fact that the possibility of drinking was restricted to the end of the interfood intervals in the present study, food-deprived rats continued drinking in association with a food delivery schedule. Interfood intervals are like interruptions of naturally occurring bouts of feeding, and because rats are highly motivated to drink after eating, SIP might occur because postfood drinking is triggered very frequently under intermittent food reinforcement schedules (Lucas, Timberlake, & Gawley, 1988, 1989). Timberlake (1990) proposed three kinds of interingestion responses related to cycles of foraging: postreward search, general search and wait, and prereward search. Drinking at the end of the interfood interval might be due to the high level of activity produced by the motivational state of the prereward search (Reid, Piñones Vazquez, & Alatorre Rico, 1985; Timberlake & Lucas, 1991). Alternative explanations for the excessive nature of the behavior rely on the displayed activities that occur in conflictive or highly motivating situations, such as those involving the withdrawal of food from hungry animals (Falk & Kupfer, 1998).

The present results show clearly that SIP can be developed in portions of the interfood interval other than the postpellet period. Drinking during these periods had several of the characteristics normally found in SIP: excessiveness, an inverted U-shaped distribution, and persistence. However, more research is needed to clarify if this behavior reflects something more than a pattern of foraging.

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