The Effect of Pairing a Stimulus with Food on Pellet-Controlled Licking in the Rat

Wendell Stone
Western Michigan University
THE EFFECT OF PAIRING A STIMULUS WITH FOOD ON PELLET-CONTROLLED LICKING IN THE RAT

by

Wendell Stone

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
Kalamazoo, Michigan
August 1975
ACKNOWLEDGEMENTS

The author would like to express his appreciation to his committee members, Dr. David Lyon, Dr. Arthur Snapper, and Dr. Kay Malott for their advice, guidance, and patience in the completion of this manuscript.

Wendell Stone
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>EXPERIMENT 1</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Method</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Subjects</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Apparatus</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Procedure</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Results</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Discussion</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>EXPERIMENT 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Introduction</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Method</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Subjects</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Apparatus</td>
<td>13</td>
</tr>
<tr>
<td></td>
<td>Procedure</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Results</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Discussion</td>
<td>28</td>
</tr>
<tr>
<td>3</td>
<td>EXPERIMENT 3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Introduction</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Method</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Subjects</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td>Apparatus</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Procedure</td>
<td>33</td>
</tr>
</tbody>
</table>
Results ................................................. 34
Discussion ............................................. 41
GENERAL DISCUSSION ................................. 43
REFERENCES ............................................. 47
The spaced delivery of 45-mg Noyes pellets to food-deprived rats generates characteristic patterns of excessive water drinking, defined as polydipsia (cf. Falk, 1972, for a comprehensive review). While this effect was first reported with rats responding under variable-interval (VI) reinforcement (Falk, 1961a), its generality has subsequently been extended to variable-time (VT) (Falk, 1961b), fixed-ratio (FR) (Falk, 1961b), fixed-interval (FI) (Falk, 1966), fixed-time (FT) (Segal, 1965; Segal, Oden, & Deadwyler, 1965), and differential reinforcement of low rate (DRL) schedules of reinforcement (Segal & Holloway, 1963). The drinking is considered excessive for three reasons. First, the quantity of water consumed is substantially greater than the quantity of water consumed in a 24-hr period (Falk, 1972). Second, the amount consumed during a spaced pellet schedule is considerably higher than when an equal number of pellets is given to the organism all at once (Reynierse, 1966). Third, the excessive water intake is physiologically damaging to the organism (Stricker & Adair, 1966).

Several explanations of polydipsia have been advanced. Stein (1964) suggests that since rats normally drink after eating, increasing the number of eating periods by spacing pellet deliveries increases the number of drinking periods, resulting in an overall increased rate of water consumption. Clark (1962) presents an operant interpretation of polydipsic behavior, with drinking
being maintained by adventitious correlations with the occurrence of pellet deliveries. Falk (1971) rejects both of these interpretations and views polydipsia as a member of a separate class of behavior—adjunctive behavior, defined as behavior whose probabilities are determined by variables controlling another class of behavior.

Although the scientific understanding of polydipsia is far from complete, it is generally recognized as a reliably occurring, experimentally manipulable phenomenon. Apparently, the sufficient conditions for the development of polydipsia are a food-deprived organism, the availability of water, and some minimum spacing of food deliveries. All of the schedules on which polydipsia have been observed involve periods during which the probability of another pellet occurring is low (i.e., following pellet delivery) and drinking is predominantly restricted to those periods. In an environment restricted to a food cup, a drink tube, and possibly a response lever, the eat-drink sequence is highly stereotyped and reliably occurring.

The results of recent investigation employing second-order schedules (Rosenblith, 1970; Wuttke & Innis, 1972) have suggested that the usual post-pellet drinking can be conditioned to occur to a non-food stimulus. Rosenblith (1970), using rats responding on FR3 (FI 1-min), observed drinking following 2-sec light flashes and clicks that signalled the end of each FI 1-min component. Wuttke and Innis (1972) employed an identical schedule (as a baseline for drug manipulations) and observed similar drinking patterns
following the completion of individual Fl 1-min components.

An explanation of this drinking that followed the light flash and click in a classical conditioning paradigm was developed by Rosenblith (1970). She suggested that drinking is an unconditioned response (UR) to food, the unconditioned stimulus (US). Drinking that followed the light flash and click stimulus was a conditioned response (CR), with the light flash-click being a conditioned stimulus (CS) by virtue of its pairing with food (the US) in the terminal Fl 1-min component.

Segal and Deadwyler (1965) have provided further support for the notion that pellet-controlled drinking is conditionable within a classical paradigm. Their procedure involved training rats on a DRL schedule of pellet delivery, and then initiating extinction (EXT) conditions during which responses that met the DRL requirement operated an empty food dispenser. Two of the three rats used as subjects showed some drinking following the dispenser click. This drinking could be interpreted as a CR, with the click functioning as a CS through its consistent temporal contiguity with the occurrence of a pellet (US).

The present series of experiments was designed to determine the conditionability of pellet-controlled drinking within a classical conditioning paradigm. In this report, classical conditioning terminology is used in referring to stimuli and responses, largely because of ease of reference rather than theoretical considerations. It is recognized, however, that according to some definitions a response need not be unlearned or reflexive to be classified as a UR if it reliably occurs following the delivery of a
stimulus (Gormezano, 1966; Hilgard & Marquis, 1940). In the case of polydipsia, the occurrence of a spaced pellet reliably results in drinking after only short periods of exposure to the pellet delivery schedule, thus justifying a reference to the pellet and subsequent drinking as a US and UR, respectively. Experiment 1 employed a discriminated VT pellet schedule to determine whether pairing a neutral stimulus with the presentation of food would increase the probability of drinking during that stimulus.

Method

Subjects

Four experimentally naive male Sprague-Dawley rats, approximately 80 days old at the start of the experiment were used as subjects. The animals were maintained at 80% free-feeding weight throughout the experiment and water was freely available in the home cages.

Apparatus

Two experimental chambers were used, both housed in sound attenuated refrigerators fitted with forced-air ventilation. Chamber 1 had interior dimensions measuring 8 X 9 X 7.75 in, with 2 walls and the hinged ceiling constructed of unpainted aluminum. The grid floor consisted of .15 in steel bars spaced .5 in apart. Mounted on one aluminum wall was a Chicago Miniature 27F 230 lamp enclosed in a frosted lamp socket mounted 1.75 in from the chamber
ceiling equidistant from the adjoining plexiglas walls above the food cup and response lever. Chamber 2 had inside dimensions measuring 8 X 8 X 8.5 in with 3 walls and chamber ceiling constructed of unpainted aluminum and the fourth plexiglas wall hinged to form a door. House illumination consisted of a small exposed Chicago Minature 27F 230 lamp centered on the chamber ceiling. Both chambers contained a nonfunctional response lever and a 1 X 1 in food opening located 1.25 in (Chamber 1) or .75 in (Chamber 2) from the grid floor and 1 in (Chamber 1) or .75 in (Chamber 2) from the adjacent plexiglas wall, on which was mounted a drink tube protruding approximately .20 in into the chamber and connected to a water reservoir. Each drink tube was mounted equidistant from the adjoining walls on the wall to the left of the food opening and 1.2 in (Chamber 1) or 1.5 in (Chamber 2) from the chamber floor. Both chambers were equipped with electronic circuit lickometers to record the subjects' contacts with the drink tubes. All pellets used were standard 45-mg Noyes pellets. Control of stimulus events in the chambers and recording of response outputs was effected through a PDP8-L minicomputer (Digital Equipment Corporation) interfaced to the experimental chambers in an adjacent room. Permanent records were obtained via on-line data prints from a Teletype.
Procedure

Four rats were designated as either Experimental (N=2) or Control (N=2) subjects. All Ss were given one session of magazine training consisting of the delivery of 40 pellets over a period of 40-45-min. Following magazine training, the Experimental Ss were exposed to a procedure in which a tone (Sonalert, 2900 Hz) was presented, terminating 15-sec later simultaneous with the delivery of a pellet. Each tone-food pairing constituted a trial. Each trial was separated by a variable amount of time ($\bar{X}=75$-sec; range 5-165-sec; 20 intervals). Both Experimental Ss were exposed to this procedure for 15 daily sessions at 100 trials/session for a total of 1500 trials.

The Ss designated as Control Ss were exposed to a Truly Random procedure suggested by Rescorla (1967) as an adequate control for a classical pairing procedure. Specifically, two independent time distributions were used to program each presentation of the tone and the pellet. The two stimulus events occurred with equal frequencies during the session, however, since the two time distributions were completely independent, the pellet could occur at varying times during the tone or during the interval between tones. The same time interval distribution for tones used in the Experimental procedure was used in the Control procedure. The distribution controlling the occurrences of pellets had a range and mean that was 15-sec greater than the distribution for tone onsets in order to effect 90-sec spacing of pellets (on the average) as in
the Experimental procedure. For the Control procedure, each 15-sec tone presentation constituted a trial. Exposure to this procedure lasted for 15 daily sessions at 100 trials/session for a total of 1500 trials.

Results

The rate of licking during the tone, expressed as a percentage of the total number of licks occurring during each session, is plotted for all Experimental and Control Ss in Figure 1. In general, both Experimental Ss show an initial sharp decrease in licking rate during the tone followed by a gradual increase across session. The rate of one Experimental S (E1) decreased from 15.07% on Session 1 to a low of 3.34% by Session 6, thereafter showing a slow steady increase in rate of licking during the tone, averaging 8.85% for the last two sessions. The other Experimental S (E2) showed a similar pattern but having a generally lower rate. E2's rate decreased from 6.64% on Session 1 to a low of 1.46% on Session 7, followed by a gradual increase in rate, averaging 9.55% for the last two sessions. Rates during the tone for the Control Ss were more stable, with percent licks during the tone for one Control S (C1) varying between 13.92% and 16.43% for all 15 sessions of exposure to the procedure. The other Control S (C2) showed only slightly more variability, with rates ranging between 13.71% (Session 11) to 19.14% (Session 5). While there is session-to-session variability, the data for both Control Ss fail to show any consis-
Figure 1. Per Cent of Total Session Licks Occurring During the Tone Over Sessions.
tent trend during the course of the experiment.

Discussion

These data indicate that a procedure involving the pairing of a stimulus and the delivery of a pellet does not result in an increase in licking during that stimulus. Furthermore, using the rate of licking during the tone of the Control Ss as baseline, the consistently lower rate shown by the Experimental Ss suggests a possible inhibitory effect of the pairing.

Within each 90-sec period, on the average, for both Experimental and Control Ss, the tone was present for 15-sec (i.e., about 16.67% of the total session time). Both Control Ss showed a percentage licking rate during the tone approximately equal to this value; 14.86% and 15.99% for C1 and C2 respectively (based on data from all 15 sessions). The values for E1 and E2 were 7.19% and 5.14% respectively. Visual observation of Ss showed reliable patterns of post-pellet licking. If, within a short interval following pellet delivery the tone came on, typical behavior for Experimental Ss was to shortly terminate the drinking bout and move to the food cup. The Control S showed no such consistent behavior, with little observable change in the pellet-controlled licking as a result of the onset and/or presence of the tone.

Although these results are not typical of those generated by classical procedures where a UR (licking in this case) comes to occur in some form during a CS, both the licking data and visual
observation support the notion that some type of conditioning is occurring as a result of pairing a tone and pellet delivery, and that this conditioning is evidenced in the form of a decrease rather than an increase in licking behavior during a tone CS. A second experiment was designed to directly test this notion.
EXPERIMENT 2

When a classical CS-US pairing is superimposed on an operant baseline, the effect is typically a decrease in rate of behavior. This conditioned suppression effect was first reported using an aversive US by Estes and Skinner (1941). Although this procedure has most extensively been investigated using electric shock US's and positively-reinforced operant baselines (cf. Lyon, 1968, for a comprehensive review), a similar suppression effect has been reported on less clearly operant behavior. For example, Hutchinson, Renfrew, and Young (1971) reported that when a stimulus is paired with the response-independent delivery of shock, bar-biting behavior that is generated by the delivery of shock, comes to occur during the early part of the pre-shock stimulus, but is suppressed toward the end of that stimulus. These data, together with the work showing suppression of an appetitively-maintained operant rate during a stimulus that precedes the delivery of response-independent food (Azrin & Hake, 1969), suggests that an ongoing licking rate may be suppressed during a stimulus that is always followed by the delivery of food. Experiment 2, using a nondiscriminated FT baseline schedule of pellet delivery was designed to investigate this notion through within-session comparisons of post-pellet licking rates during the presence and absence of a 15-sec tone stimulus which was always terminated with the delivery of a pellet(s). The size of the US, defined as the number of pellets occurring at the
end of the tone, was also varied to determine if a direct relation
exists between US size and degree of suppression as has been re-
ported by Annau and Kamin (1961) using aversive US's and appeti-
tively-maintained operant baselines.

Method

Subjects

Three experimentally naive male Sprague-Dawley rats approx-
imately 90 days old at the start of the experiment were used as sub-
jects. The animals were maintained at 80% free-feeding weight dur-
ing the experiment. Water was freely available in the home cages.

Apparatus

The apparatus used in Experiment 1 was used in Experiment 2, with the addition of one chamber measuring 7.25 X 8.5 X 7.5 in. Two walls and a hinged ceiling were constructed of clear plexiglas and two walls were painted black aluminum. A 1.25 X 1.75 in food cup extended into the chamber and was mounted 5.75 in from the ceil-
ing and 1 in from the left plexiglas wall on which was mounted a drink tube 1 in from the floor and equidistant from the adjoining walls. The grid floor consisted of 1.5 in diameter steel bars spaced .5 in apart. House illumination was an exposed Chicago Miniature 27F 230 lamp mounted 1.5 in from the right wall and 1.5 in from the ceiling. This chamber also contained a nonfunctional re-
spone lever on the same wall as the food cup.
Procedure

Following one session of magazine training (as in Experiment 1) each $S$ was exposed to a complex schedule of pellet delivery. The baseline schedule consisted of the delivery of a pellet every 90-sec on a fixed basis (FT 90-sec). The delivery of a pellet and the first 15-sec of the post-pellet period constituted a trial. Two types of trials were given during each session. On CS trials, immediately following the delivery of a pellet, a tone came on which coterminated with the delivery of a second pellet 15-sec later. On nonCS trials, no tone or second pellet occurred. Twenty CS trials were delivered on a variable basis during each daily 100-trial session. Each of three $S$s (designated as FT1, FT2, and FT3) continued on this procedure for 16 sessions, after which the number of pellets following the tone was geometrically increased from 1-, to 2-, to 4-pellets with six sessions of exposure to each condition. Finally, for six sessions for $S_{FT3}$, and 12 sessions for $S$s FT1 and FT2, an EXT condition was in effect, defined as the presentation of the tone followed by 0-pellets. $S_{FT1}$ was given six sessions under an additional EXT procedure defined as the presentation of 0-pellets and no tone on CS trials.

Results

The 15-sec period following the delivery of each FT 90-sec pellet was divided into successive 5-sec segments and the mean number of licks occurring in each segment for each session was computed
separately for CS and nonCS trials. These data are plotted in Figures 2, 3, and 4, for Ss FTl, FT2, and FT3, respectively. The uppermost pair of lines in each figure represents the mean number of licks occurring during the first 5-sec (0-5-sec) of the 15-sec trial period for CS trials (solid symbols) and nonCS trials (open symbols) for successive sessions. Similarly, the middle and bottom pairs of lines show the mean number of licks occurring during the second (6-10-sec) and third (11-15-sec) 5-sec segments, respectively. The data points for Sessions 1-4 for S FTl, and for Session 1 for S FT2 are not available.

In general, for each S under the 1-pellet condition, the rate of licking during the 0-5-sec period on CS trials was higher than the rate on nonCS trials, although rates were near zero for the first few sessions on both types of trials. The rates on CS and nonCS trials during the 6-10-sec period were essentially equal and the rates during the 11-15-sec period were lower on CS trials. Increasing the number of pellets coterminating with the tone resulted in little change in these relationships between rates on CS and nonCS trials for S FTl. S FT2, however, showed a substantially lower rate on CS trials during the 6-10-sec period which was consistent for the final four sessions under the 2-pellet condition. S FT3, although maintaining the general relationships between rates on the two types of trials during the 2-pellet condition, showed a sharp drop in rate during all CS trial segments on the final session. This resulted in CS trial rates lower
Figure 2. Mean Number of Licks During 5-sec Segments of CS and nonCS trials; S FT1.
Figure 3. Mean Number of Licks During 5-sec Segments of CS and nonCS Trials; S FT2.
Figure 4. Mean Number of Licks During 5-sec Segments of CS and nonCS Trials; _FT3.
than nonCS trial rates during the 0-5-sec and 6-10-sec segments, increasing the already lower rate in the 11-15-sec period.

The initiation of the 4-pellet condition had no noticeable effect on the trial data for S FT1. For S FT2, the relatively lower rate during the 6-10-sec period on CS trials that was first evidenced during training under the 2-pellet condition was also true for each session using the 4-pellet US. CS trial rates higher in the 0-5-sec period and lower in the 11-15-sec period (relative to nonCS trial rates during these same periods) were maintained for this S during these sessions. S FT3, which had shown licking rates lower in all CS trial segments than in nonCS trial segments during the last session under 2-pellets, continued to show these relationships during the 4-pellet condition with the effect accentuated in the 6-10-sec and 11-15-sec segments.

When the EXT procedure was instituted, during which the tone terminated with the delivery of 0-pellets, the rates during the 11-15-sec period, which had been lower for each S on CS trials under previous conditions, became essentially equal to the rates on nonCS trials for Ss FT1 and FT3. S FT2 showed higher licking rates on CS trials during this period for each of the 12 sessions of its exposure to the 0-pellet condition.

No change in the essentially equal rates on nonCS and CS trials during the 6-10-sec segment for S FT1 occurred as a result of training on the 0-pellet condition. The higher rates on CS trials for S FT2 continued throughout the 0-pellet condition, although rates on both types of trials became very low during this
S's exposure to this condition. FT3, which had shown considerably lower rates on CS trials during the 6-10-sec period using the 4-pellet US, showed equalization of rates on CS and nonCS trials under the 0-pellet condition together with substantially decreased rates on both types of trials during this period after the first few sessions of exposure to the procedure.

In the 0-5-sec trial segment, FT1 continued to show rates on CS trials slightly higher than those on nonCS trials for 12 sessions. When the tone was eliminated for this S, thus effecting no difference in stimulus conditions between CS and nonCS trials, the rates became nearly equal during the 0-5-sec period. FT2 showed higher rates on CS trials during this period for the first few sessions under the 0-pellet condition after which rates on both CS and nonCS trials were at or near zero. The third S, FT3, showed rapid equalization of CS and nonCS trial rates during the 0-5-segment within a few sessions of training under this condition.

In order to determine the overall effect of US size on the licking behavior during each of the three 5-sec segments of the 15-sec trial period following the delivery of each FT 90-sec pellet, an index of suppression (after Fleshler & Hoffman, 1961) for each segment was computed by subtracting the rate of licking on CS trials from the rate on nonCS trials and dividing that difference by the rate on nonCS trials. With this ratio, a value of 1.00 indicates complete suppression of licking on CS trials, .00 indicates no difference in rates, and acceleration during CS trials
results in negative values. The ratios computed for the 1-pellet (based on the last six sessions of exposure), 2-pellet, and 4-pellet conditions (both based on all six sessions of exposure) and the 0-pellet condition (based on the first six sessions) are plotted in Figure 5 for each S. Because of very large negative values, all ratios for the 0-5-sec period and for the 6-10-sec period under the 0-pellet condition for S FT2 could not be included in Figure 5.

The data for S FT1 show essentially no effect of US size, having stable suppression during the 11-15-sec period on CS trials reflected by the ratios for the 1-, 2-, and 4-pellet conditions of .49, .41, and .49, respectively. When no pellets were delivered at the end of the tone under the 0-pellet condition, no suppression was present, with the first six sessions under this procedure resulting in a ratio of -.07 for the 11-15-sec period. Data for the last six sessions gave a ratio of .00, as did the six sessions under the 0-pellet and no tone condition. During the 6-10-sec trial segment, S FT1 showed consistently equal rates on CS and non-CS trials reflected by suppression ratios near zero (between -.04 and .05) under all conditions. There were larger changes in the values for the 0-5-sec period across US sizes, with ratios of -.38, -.79, and -.53 for the respective 1-, 2-, and 4-pellet conditions. Evidence of higher rates on CS trials was also present during the first and last six sessions of the 0-pellet condition which had ratios of -.35 and -.28. With no difference in stimulus conditions during the 0-pellet and no tone procedure, the ratio
Figure 5. Suppression Ratios for 5-sec Trial Segments as a Function of US Size.
for the 0-5-sec period was near zero (-.04).

The ratios for the 11-15-sec period computed from the data generated by $S$ FT2 also appeared to show no consistent trend with increases in US size. Changing from the 1-pellet to 2-pellet condition showed a change in suppression ratios from .38 to .45. Corresponding to an increase in US size to 4-pellets was a decrease in the suppression ratio to .32. Data from the first and last six sessions of the 0-pellet condition resulted in the negative ratio values of -.36 and -.38, respectively. During the 6-10-sec trial segment, corresponding to the increases in US size were the increasing negative ratios of -.17, -.36, and -.81. Initiation of the 0-pellet procedure resulted in a substantially larger ratio of -3.05 (based on the first six sessions) which decreased somewhat to -1.56 in the last six sessions. Large negative ratios, which were characteristic of the 0-5-sec period for this $S$, increased across all conditions. The ratios were -1.32, -7.47, -10.41, -64.75, and .00, Corresponding the 1-, 2-, 4-pellet, and first and last six sessions of the 0-pellet condition, respectively. The .00 ratio for the final 0-pellet sessions was a result of no licks being made during either CS or nonCS trials during this period.

The suppression ratio for $S$ FT3, based on the 11-15-sec trial segment showed a decrease from .58 to .44 when the number of pellets delivered at the end of the tone was increased from 1- to 2-pellets. An increase to 4-pellets resulted in a considerable increase in the ratio to .90. Some suppression of licking on CS
trials was still evident during this S's exposure for six sessions to the 0-pellet condition, reflected by a ratio of .25 based on these sessions. Ratios for the 6-10-sec period for S FT3 increased from -.01 using a 1-pellet US, to .08 and .76, respectively, with the 2- and 4-pellet USs. As in the 11-15-sec period for this S, some suppression on CS trials was still present in the 6-10-sec period during the six sessions of exposure to the 0-pellet procedure. Higher rates on CS trials indicated by negative ratios of -.57 and -.30 during the 0-5-sec segment for the 1- and 2-pellet conditions were absent using the 4-pellet US, where the ratio of .54 showed a change to lower rates on CS trials under this condition. Under the 0-pellet procedure, the rates were approximately equal on CS and nonCS trials, as indicated by the ratio of .05.

Discussion

These data show that when a stimulus, paired with the response-independent delivery of a pellet(s), is superimposed on an ongoing rate of pellet-controlled licking, there is a decrease in that rate in the later part of the stimulus. The data presented in Figure 5 also suggest that this decreased rate is uneffected by the number of pellets coterminating with the stimulus. Excluding the effect of the 0-pellet EXT procedure, the curves for each of the 5-sec trial periods are flat for S FT1. Each of these curves for S FT2, is negatively sloping, indicating relative increases in CS trial rates across experimental conditions. Examina-
tion of Figure 3 for this S, however, shows that these changes in suppression ratios were largely determined by variation in nonCS trial rates. While the CS trial rates remained relatively stable across the 1-, 2-, and 4-pellet conditions, the nonCS trial rates showed consistent decreases. To a lesser extent the data for S FT3 (in Figure 4) show variation in rates on both types of trials, suggesting that the functions for this S in Figure 5 were not determined solely by the effect of the number of pellets delivered at the end of the tone on the rate of responding during that tone. Despite these variations, the lower rates of licking during the 11-15-sec period were consistent for each of the three Ss used when the tone was paired with the delivery of food, and the rate increased when an EXT procedure was initiated, supporting a position that the decreased rate was a result of the pairing.

In addition to the suppression effect, the presence of the CS during the post-pellet drinking period resulted in higher rates of licking during the initial portion of that CS when using 1-, 2-, and 4-pellet USs for two Ss (FT1 and FT2), but only during the 1- and 2-pellet conditions for the third S (FT3). That this effect was a result of the pairing of the tone with food was shown to be doubtful for Ss FT1 and FT2 because the higher rates continued throughout 12 days of exposure to a procedure where no pellets were paired with the tone. The 0-pellet and no tone condition to which FT1 was exposed for six sessions was a test for the apparently higher rates on CS trials during the 0-5-sec period.
being a result of an undetected error in the recording method. Such was not the case since, within a small number of sessions under this procedure, the increased rates were eliminated. At least for S FT1, the higher rates on CS trials during the first few seconds were largely a nonassociative effect of the tone presentation. S FT2 showed these higher CS trial rates during the first two 5-sec trial segments under the 2- and 4-pellet conditions and also during the 11-15-sec period under the 0-pellet condition (see Figures 3 and 5). The origin of this general facilitative effect may be attributable to four sessions during which equipment failures resulted in this S's exposure to an undetermined number of pellet-feeder operations (clicks) without pellet deliveries (on both CS and nonCS trials). Since, during a given amount of experimental time, more nonCS trials are given than CS trials, the effect of these failures (which occurred during the 2- and 4-pellet conditions) could be expected to be greatest on licking occurring on nonCS trials. The variation (decreases) in nonCS trial rates shown in Figure 3 supports this explanation.

Taken as a whole, the results of Experiment 2 support the notion that a stimulus paired with food does result in decreased rates of pellet-controlled licking during that stimulus. These data are consistent with data showing the presence of a CS to result in suppression of an operant rate (Azrin & Hake, 1969). An increase in licking was found during the initial portion of the
CS, but could not be conclusively attributed to the CS-US pairing. These data, together with the data generated by the procedures used in Experiment 1, provide additional support for the idea that a classical pairing does not result in an increase in licking during the CS. A third experiment was performed to determine if the pairing would result in licking following the CS on periodic test (CS alone) trials.
EXPERIMENT 3

Although the data from Experiments 1 and 2 support the position of no increases in licking during a CS paired with food, another test for conditioning involves measurement of behavior following the CS with the US omitted on test trials (Hilgard & Marquis, 1940). Rather than a neutral stimulus acquiring the capacity to elicit a response formerly controlled by the presentation of the US only, conditioning (in the form of increases in licking) of polydipsic behavior may be evidenced in licking that follows the offset of a CS on periodic test trials. In other words, in the polydipsia paradigm, the CS may be functioning as the pellet and licking usually controlled by the recent delivery (and consumption) of the pellet may come under the control of the recent delivery (and "consumption", i.e., offset) of a CS. Experiment 3 was performed to test this notion through the measurement of licking distributions following the delivery of the CS on periodic test trials (without the pellet), following a period of its consistent pairing with the delivery of the pellet.

Method

Subjects

Three male Sprague-Dawley rats, approximately 100 days old at the start of the experiment were used as subjects. The animals
were experimentally naive and were maintained at 80% free-feeding weight throughout the experiment, with water freely available in the home cages.

**Apparatus**

The same apparatus used in Experiments 1 and 2 was used in Experiment 3.

**Procedure**

During initial training, three Ss (designated as TT1, TT2, and TT3) were given one session of magazine training (as in Experiments 1 and 2), followed by nine (S TT3) or ten (Ss TT1 and TT2) sessions of exposure to a discriminated FT 90-sec pellet delivery schedule. On this procedure, a tone which coterminated with the delivery of a pellet 15-sec later occurred on a fixed basis within each 90-sec period during the session. Each tone-pellet pairing constituted a trial. Each daily session was 100 trails long.

Following initial training, each S was given five sessions during which ten test trials were delivered on a variable basis during each 100-trial session. A test trial was defined as identical to a pairing trial except that the tone terminated without the delivery of a pellet. S TT3 was given five additional sessions of exposure to this test trial procedure, followed by exposure to a second testing procedure. On this procedure, when a test trial was scheduled, neither the tone nor the pellet occurred (again, ten times on a variable basis during each session), thus
no stimulus event signalled the occurrence of a trial. S TT3's exposure to each type of testing was alternated every two sessions for the next eight sessions, giving this S four sessions of exposure to the special testing procedure (no tone or pellet) and four additional sessions of the regular testing procedure (no pellet).

Results

Licking distributions for each S from the testing sessions are plotted in Figure 6 (Ss TT1 and TT2) and Figure 7 (S TT3). Each distribution is based on the data from one session and shows the relative frequency of licking in 15-sec intervals during the 90-sec period following both pairing trials (solid circles) and test trials (open circles). The first data point, therefore, represents the relative frequency of licking in the 15-sec period following the occurrence (pairing trials) or nonoccurrence (test trials) of the pellet and the last data point is based on the licking during the 15-sec tone presentation associated with the succeeding trial. No test trial distribution was plotted unless S had a total of more than five licks following the ten test trials given during each session. The total number of licks made following the ten test trials is underlined above each session's distribution(s).

Examination of the distributions for S TT1 in Figure 6 reveals high rates of licking following each pairing trial, with between 70% and 80% of the total licks occurring in the 15-sec
Figure 6. Distributions of Licking During Testing Sessions; Ss TT1 and TT2.
Figure 7. Distributions of Licking During Testing Sessions; Ss TT3.
Pairing Trials

Test Trials

S TT3

15-sec Class Intervals
period following pellet delivery for all sessions. The second 15-
sec interval contained nearly all of the remaining 20% to 30% of
the post-pellet licks. Licking was at or very near zero during
later intervals. For all five sessions (50 test trials), S TT1
made a total of only eight licks during the post-test trial record-
ing period, six of which occurred between trials on the first
testing session, about equidistant in time from the end of the
test trial (CS offset) and the beginning of the next trial (CS on-
set).

Data from the testing sessions shown in Figure 6 for S TT2
show the highest amounts of licking following pairing trials in
the second 15-sec interval (about 40%-45%). Typically, this S had
a slightly lower licking frequency in the first 15-sec interval
following the end of the trial (about 30%-40%). The third inter-
val contained most of the remaining licks and very few licks
occurred in the other intervals. A very near zero amount of lick-
ing was characteristic of the CS period. Of the 89 licks that
occurred during the test trial recording period, 84 were made on
the first session, and as with S TT1, they occurred distant in
time from the presence of the tone CS.

The pairing trial distributions for S TT3 for the first ten
testing sessions (upper graph in Figure 7) show between 70% and
80% of the licks occurring during the 15-sec period immediately
following the end of the trial, and between 10% and 20% in the next
interval. The other intervals were characterized by relative
frequencies under 5%, which decreased with distance from the pellet and became near zero during the 15-sec interval characterized by the presence of the CS. In contrast to the data from $S_s$ TT1 and TT2, $S_s$ TT3 showed substantial amounts of licking following test trials. Although none of the test trial distributions are as orderly with respect to skewness away from CS offset as those for pairing trials, they do become more so across the first five or six sessions. The fifth and sixth sessions have test trial distributions that are the most similar to the pairing trial distributions. Although the distributions are bimodal, they show first interval relative licking frequencies of 60.32% and 46.70% for the two sessions, respectively. Sessions 7-10 show progressively flatter distributions, with substantial licking occurring in most intervals following test trials, except for the CS period.

During the next two sessions when the special no tone or pellet testing procedure was in effect (first two pairs of distributions in lower graph), licking still occurred during the test trial recording period and was nearly evenly distributed across all intervals (again excluding the period when the CS was present). Alternation of this procedure with the regular no pellet testing procedure every two sessions appeared to have no effect on the distributions. Although there was no effect of the changes in testing procedures, as a function of sessions, the testing distributions show more licking in later intervals, especially in the
final two sessions. Also as a result of successive sessions was a
tendency for the pairing trial distributions to become more strongly bimodal, an effect most obvious across the last six sessions of testing.

Discussion

These data show that when a tone is paired with the delivery of a pellet, no conditioning occurs in the form of licking following the offset of the tone without the pellet. The data are consistent with the data from Experiment 1 in that near-zero rates of licking were characteristic of the presence of the CS. They extend that data by showing the conclusion of licking as unconditionable to a tone CS with a pellet US to be applicable to the period following the CS.

Two of the three Ss (TT1 and TT2) exposed to the testing procedure showed licking that was negligible for two reasons. First, especially for TT1, the amount of licking was very small occurring on the first testing session for both Ss. Second, for both Ss, the licking occurred at a time that was distant from the occurrence of CS offset, suggesting that its determinants were not related to that stimulus event.

The third S, TT3, showed considerable licking following test trials, but again this licking could not be conclusively attributed to the occurrence of CS offset for two reasons. First, although for some sessions, the test trial distributions showed peak lick-
ing immediately following CS offset, considerable licking was also present in later intervals, a phenomenon not characteristic of most of the pairing trials. Second, when CS offset did not occur on the special no tone testing procedure to which this S was exposed, no noticeable change occurred in the licking distributions. With a lack of an effect of this manipulation, the licking that occurred during the test trial recording period could not be attributed to the occurrence of CS offset.

Suggestions as to the determinants of TT3's post-test trial licking are difficult since the distributions vary from positive skewness, suggesting control by CS offset, to flat, suggesting a mediating function (see Laties, Weiss, Clark, & Reynolds, 1965), to negative skewness, suggesting superstitious operant control by the occurrence at the trial.
GENERAL DISCUSSION

The data from Experiment 1 indicated that pairing a stimulus with the delivery of a pellet does not result in an increase in licking during that stimulus. This finding was supported by the data from Experiment 3, and was extended by showing no increase in licking following the CS on test trials with the US omitted. It can be concluded, therefore, that classical conditioning of licking controlled by pellet delivery failed to occur on the procedures reported here. A partial explanation of this general result may lie in the question of whether the delivery of the pellet is the event that evokes (i.e., is the US for) the subsequent licking.

On a spaced pellet schedule, a number of events occur following the delivery of each pellet. Any one or more of these events could be viewed as a UR(s) if a UR is defined solely in terms of its reliable occurrence following the delivery of a stimulus. When a pellet is delivered, the first events following that pellet are those behaviors necessary to physically obtain the pellet. The pellet must be consumed and then following some short latency, the S reliably licks. Some recent work (Keehn & Colotla, 1970) has suggested that even though licking is a post-pellet phenomenon, the stimulus for licking is not the delivery of a pellet. Their procedure involved rats bar-pressing on a mix Fl t-min CRF n schedule of pellet delivery. On this schedule, rats did not drink
after every pellet, but continued to respond until n number of pellets had been delivered and a bar-press or two went unreinforced before beginning to drink. These results suggest that the stimulus for drinking is not the delivery of a pellet, but is some event (discrete or time-correlated) that signals a low probability of a pellet.

If it is true that some aspect of the post-pellet period is the US for licking, then the observed lack of increases in licking during or after a CS paired with pellet delivery could be expected for at least two reasons. First, since the procedures used in these experiments specified CS offset at the end of pellet delivery, the CS was not being paired directly with the US for licking. Rather, these procedures are examples of delayed or trace conditioning procedures, depending on whether the period immediately following pellet delivery or following pellet consumption, respectively, contains the essential discriminable event that evokes licking. Second, since the CS is paired with the availability of the pellet, the behaviors occurring with respect to that CS could be expected to be those specifically associated with the pellet such as salivation, chewing, and general approach behavior (toward the food opening), rather than behavior associated with the period following the consumption of the pellet (i.e., licking). That these preparatory responses (Zener, 1937) do occur on the classical conditioning procedures reported here is given support by the data in Experiment 2, the suggestion being that the decreased rate (or
early cessation) of licking during later portions of the CS was a result of behavior directed toward the food opening and the receipt of the pellet.

The central aspect of the above explanation for no conditioning of licking is that instead of the CS being conditioned to a low pellet probability that generates licking, it was being conditioned to high pellet probability that generates consumatory behavior. Although this approach is consistent with the data reported here, it does not explain the licking observed on second-order schedules (Rosenblith, 1970; Wuttke & Innis, 1972) or the post-feeder click licking observed during EXT of DRL responding by Segal and Deadwyler (1965). The licking that both Rosenblith (1970) and Wuttke and Innis (1972) observed followed the completion of individual components of an FR3 (FI 1-min) schedule of pellet delivery. The completion of individual components was signalled by 2-sec light flashes and clicks (response-dependent) that were paired with pellet delivery in the terminal component. Unfortunately, it was not specified where the click occurred with respect to the 2-sec light flash. If it occurred at light flash offset, then the pairing was similar to the one reported here. If the click occurred at the onset of the light flash, then the presence of the light stimulus could extend past the period of pellet consumption into the early portion of the next interval, a period characterized by a low probability of pellet availability. This aspect of the procedure, in terms of what pellet probability
is paired with the CS, may be a critical variable in determining the acquisition of classically conditioned licking.

The observations of licking by Segal and Deadwyler (1965) were made on procedures that were similar to the studies employing second-order schedules (Rosenblith, 1970; Wuttke & Innis, 1972) and unlike the procedures reported here in two ways. First, the non-food stimulus following which licking was observed was the feeder click (and also the light flash in the work using second-order schedules). Second, the occurrence of the stimulus that may have been functioning as a CS for licking was dependent on responses of the organism. Although further experimentation is necessary to determine if these aspects of procedure are critical, they do represent major differences with the present work. In any case, this report provides the only quantitative investigation of the conditionability of licking, and the results indicate that it does not occur.
REFERENCES


