JOURNAL OF THE EXPERIMENTAL ANALYSIS OF BEHAVIOR VOLUME 9, NUMBER 2 MARCH, 1966

ANALYSIS OF WATER AND NaCl SOLUTION ACCEPTANCE BY SCHEDULE-INDUCED POLYDIPSIA[1]

JOHN L. FALK

UNIVERSITY OF MICHIGAN

Animals were trained on a VI 1-min schedule for food pellets, and concurrent water intake was measured. The polydipsia induced was analyzed in terms of the frequency distribution of post-pellet licking burst sizes and the trend of polydipsia throughout the session. An ascending series of NaCl solutions was presented consecutively over daily sessions and a typical NaCl acceptance-rejection intake function was generated. Beginning in the 0.9-1.2% NaCl range, the animals drank less often during the session but took larger drinks when they did drink. Neither the frequency of drinks nor the mean licking burst size were simply related to the volumes of NaCl solution consumed. The NaCl acceptance-rejection function cannot be explained in terms of water repletion factors alone.

Several investigators (Bare, 1949; O'Kelly, 1954; Weiner and Stellar, 1951; Young, 1949) have noted that NaCl solutions in the hypotonic and isotonic range are more acceptable to the rat than plain water, but the major determinants of this phenomenon have not yet been clarified. Explanations appealing to the relative rehydration properties of saline solutions for water-deprived animals are not conclusive since NaCl-solution preferences can be demonstrated under nondeprivation conditions by brief-choice testing (Young and Falk, 1956; Falk and Titlebaum, 1963).

Another experimental preparation for evaluating fluid acceptance in the absence of water deprivation is the intermittent delivery of food pellets to a food-deprived animal which produces schedule-induced polydipsia (Falk, 1961*a*; Falk, 1961*b*; Falk, 1964). In the present experiment, an ascending series of NaCl solutions was presented to animals with established schedule-induced polydipsia to ascertain the pattern of acceptance under conditions inducing high fluid intakes without water deprivation. NaCl solution intakes on four animals subjected to this procedure were reported previously (Falk, 1964), although the method of recording and the lack of a printing counter prevented retrieval of the explicit individual functions revealed in the present experiment.

METHOD

Subjects

Two female albino rats of the Hisaw strain, designated HI-1 and HI-3, were used. They were littermates, 120 days old at the start of the experiment, and were housed individually in a constantly-illuminated temperature-controlled room.

Procedure

The animals were maintained at 80% of their free-feeding weights on a 1-min VI food-reinforcement schedule for 45 mg Noyes lab rat food pellets. Daily 3.5-hr VI 1-min sessions were run and any food supplement necessary to maintain the running weight was given immediately after the session. The experimental space was a picnic ice chest containing a Gerbrands lever and a food magazine. The spout of a calibrated water reservoir was available through a slot cut in a Micarta panel. Licks at the spout were detected electronically by a drinkometer circuit and recorded in another room. Water was continuously available to the animals in their home cages.

Bar-pressing behavior was shaped and maintained for a few sessions with continuous reinforcement. Then the animals were exposed to the VI 1-min contingency. Within approximately four weeks session water intake had

[1]This research was supported by United States Public Health Service Grant B3861, Atomic Energy Commission Contract AT(11-1)1201, and United Cerebral Palsy. Reprints may be obtained from the author, Department of Pathology, The University of Michigan, Ann Arbor, Michigan 48104.

stabilized. The drinking pattern of the next 10 consecutive sessions was analyzed with the aid of a printing counter.

After several further water sessions were run to ensure that a stable baseline was being maintained, the following NaCl solutions were substituted for water in the reservoir in an ascending order of concentration over consecutive days: 0.1%, 0.3%, 0.6%, 0.9%, 1.2%, 1.8%, 2.1%, 3.0%. Water remained available in the home cage as usual.

RESULTS

The number of pellets earned per session with VI 1 min varied only slightly with response rate when sessions were terminated by a clock as long as the response rate did not fall too low. Rat HI-1 earned between 189 and 197 pellets per session, while HI-3 earned 178-184 pellets. Figure 1 shows the mean 10-day frequency-distribution histograms of post-pellet lick burst size for each rat. The three columns to the right in Table 1 present analyses of the same 10-day period. Both animals were polydipsic during the experiment sessions in comparison to their pre-experimental water intakes. Post-pellet licking bursts amounted to over ½ ml water intake for the mode burst for both animals.

Figures 2 and 3 show plots of the median post-pellet lick burst size for each successive group of 10 pellets throughout the session for 10 sessions. A line is drawn through the median of these 10-day medians. The plots reveal that the median burst was greatest in the initial portion of the session and then maintained a fairly constant size.

Figures 4 and 5 reveal NaCl acceptance-rejection intake functions. As the concentration of NaCl solution was increased through the hypotonic range, more fluid was consumed than when water was offered. As the concentration made available became more hypertonic, progressively less drinking occurred. But even

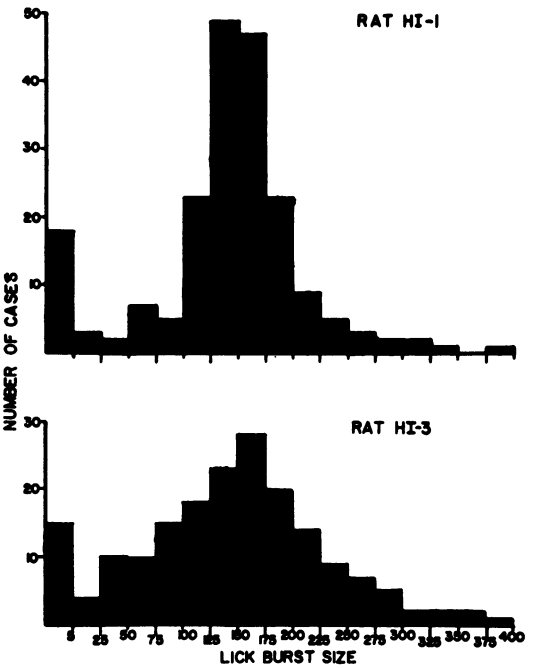

Fig. 1. Ten-day mean frequency distributions of post-pellet lick burst size.

at 3.0% NaCl, HI-1 consumed 21 ml and HI-3 consumed 23 ml. As NaCl concentration was increased, the number of instances where an animal failed to drink at all before earning the next pellet increased throughout the hypertonic range (Fig. 4 and 5). Ignoring these zero-size lick bursts, when the mean lick burst size is plotted as a function of NaCl concentration both animals show a marked increase well into the hypertonic range. In fact, the mean session lick burst sizes were largest in the 1.2-2.1% range. This is well into the descending or rejection limb of the intake curve for both animals.

Figure 6 shows a typical water session for HI-3 and the session in which 0.9% NaCl was available. Licks step the recorder vertically and pellet delivery resets the pen to the bottom of the record. Pellet delivery is also marked on the event channel below the

Table 1

Means ± Standard Errors

Rat	*Pre-experimental 24-hr water intake (ml)*	*3.5-hr Session Water Intake (ml)*	*Licks/ml*	*Ml/Mode Drink*
HI-1	21.0 ± 0.75	102.7 ±1.28	258.6 ± 8.02	0.620 ± 0.019
HI-3	19.5 ± 0.83	82.9 ± 1.97	319.4 ± 7.53	0.544 ± 0.033

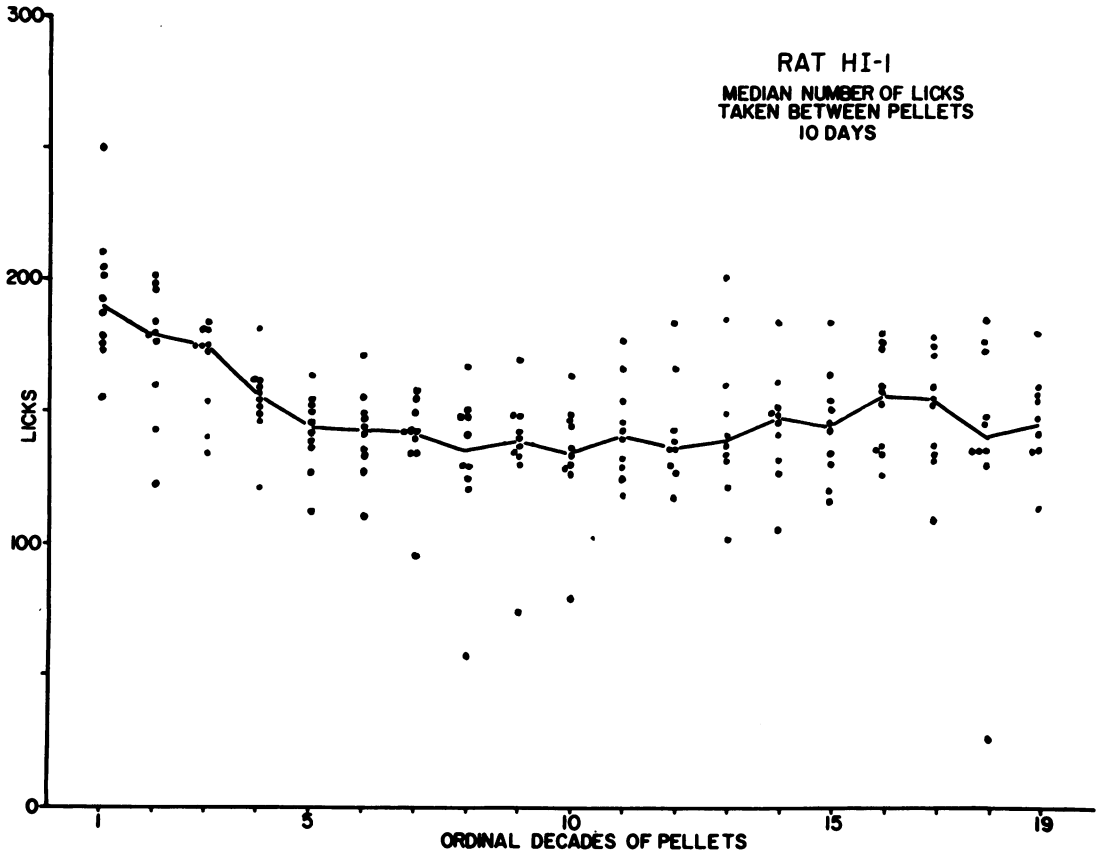

Fig. 2. Median post-pellet lick bursts throughout session (10 sessions) for Rat HI-1.

stepped record so that instances where pellet delivery was not followed by licking could be noted. Bar-pressing on the VI 1-min schedule was not recorded on the graphic record. The two records are quite similar, although Fig. 5 shows that the intake for 0.9% NaCl was greater (99 ml) than in the case of water sessions.

Figure 7 shows a water session and the three highest NaCl concentration sessions for HI-1. It reveals directly what can be inferred from Fig. 4: while the number of zero lick bursts increased through the hypertonic range, the mean lick burst size, excluding zero bursts, was well above the magnitude for water. This was the case for both animals. While drinking became less frequent with increasing fluid tonicity, the mean size of the draughts taken increased. This is further analyzed in Fig. 8 and 9, which show the ascending NaCl solution series and the preceding three water days. The progressive shift in the burst-size distribution is striking for both animals.

DISCUSSION

The NaCl solution acceptance-rejection intake functions were similar in shape to the NaCl curves obtained by water deprivation methods (Bare, 1949; Weiner and Stellar, 1951; Titlebaum, Falk, and Mayer, 1960), although the volumes consumed under the present method were of a higher order (see Falk, 1964, for explicit comparisons). In a previous study (Falk, 1964), four animals given a series of NaCl solutions under conditions identical to the present experiment, yielded similar curves. The NaCl preferences revealed by the brief-choice method (Young and Falk, 1956) under nondeprivation conditions, and the relative NaCl solution volumes accepted by nondeprived polydipsic animals, preclude any comprehensive explanation of these functions which is framed solely in terms of fluid repletion considerations.

The increasing incidence of zero lick bursts as the NaCl concentration offered was in-

creased through the hypertonic range may be a more sensitive indicator of the aversive property of a solution than the volume consumed. The zero-burst functions began to rise at concentrations where larger volumes of solution were being ingested than was the case when plain water was available. The threshold for a rise in zero bursts seems to lie at about 0.9% for HI-1 and 1.2% for HI-3. The thresholds for four previous animals (Falk, 1964) also lay in the 0.9-1.2% range.

Perhaps the most unexpected result was the increased mean lick burst size in the strongly hypertonic range. This does not correlate with intuitive notions of preference and acceptance since intake volume fell sharply and zero bursts rose in this range. There is no ready explanation for this phenomenon, but previous work has shown that where water repletion was not a prime consideration, normal rats would prefer concentrations of NaCl well into the hypertonic range for certain periods of time (Young and Falk, 1956, *cf.* Table 1, group I, and Table 2).

REFERENCES

Bare, J. K. The specific hunger for sodium chloride in normal and adrenalectomized white rats. *J. comp. physiol. Psychol.*, 1949, **42**, 242-253.

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

Falk, J. L. The behavioral regulation of water-electrolyte balance. In M. R. Jones (Ed.), *Nebraska symposium on motivation: 1961*. Lincoln: Univ. Nebraska Press, 1961*b*, pp. 1-33.

Falk, J. L. Studies on schedule-induced polydipsia. In M. J. Wayner (Ed.), *Thirst: first international symposium on thirst in the regulation of body water*. New York: Pergamon Press, 1964, pp. 95-116.

Falk, J. L. and Titlebaum, L. F. Saline solution preference in the rat: further demonstrations. *J. comp.*

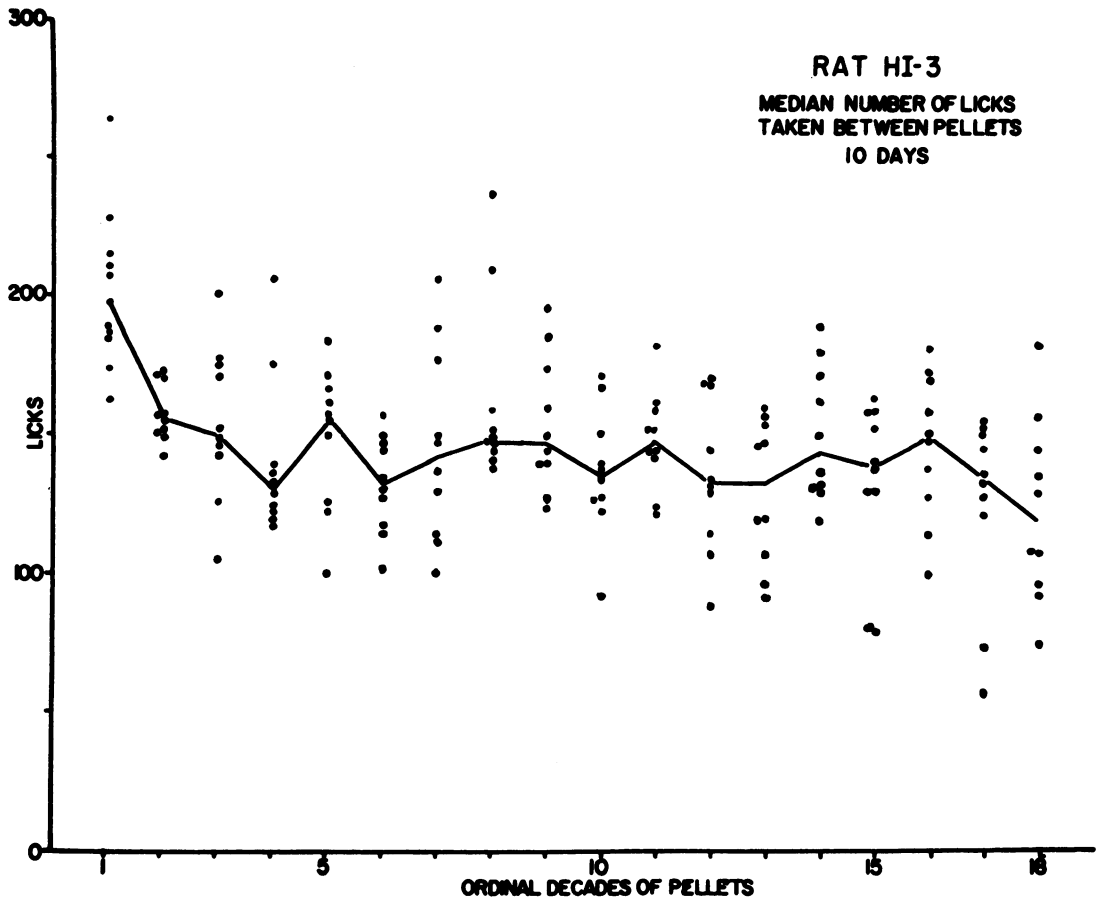

Fig. 3. Median post-pellet lick bursts throughout session (10 sessions) for Rat HI-3.

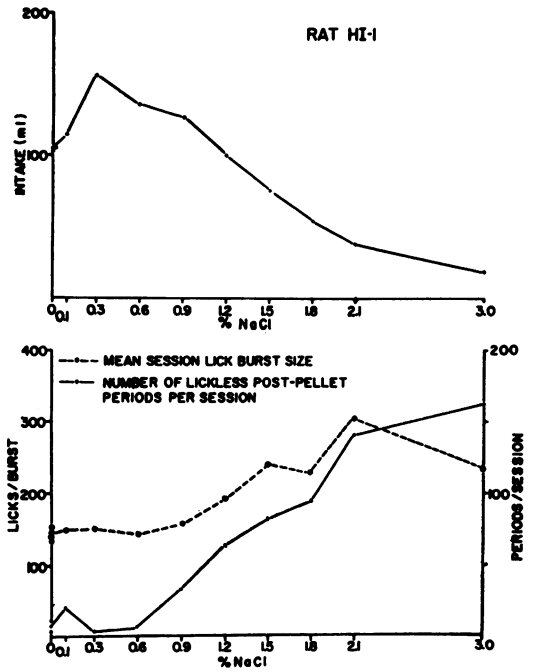

Fig. 4. Rat HI-1. NaCl solution acceptance-rejection intake function resulting from schedule-induced polydipsia (upper). Mean lick burst size and incidence of zero size post-pellet bursts as a function of NaCl concentration (lower).

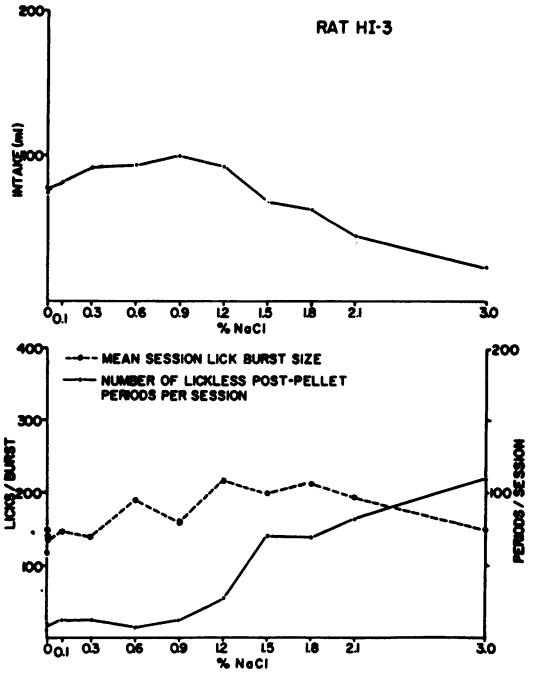

Fig. 5. Rat HI-3. NaCl solution acceptance-rejection intake function resulting from schedule-induced polydipsia (upper). Mean lick burst size and incidence of zero size post-pellet bursts as a function of NaCl concentration (lower).

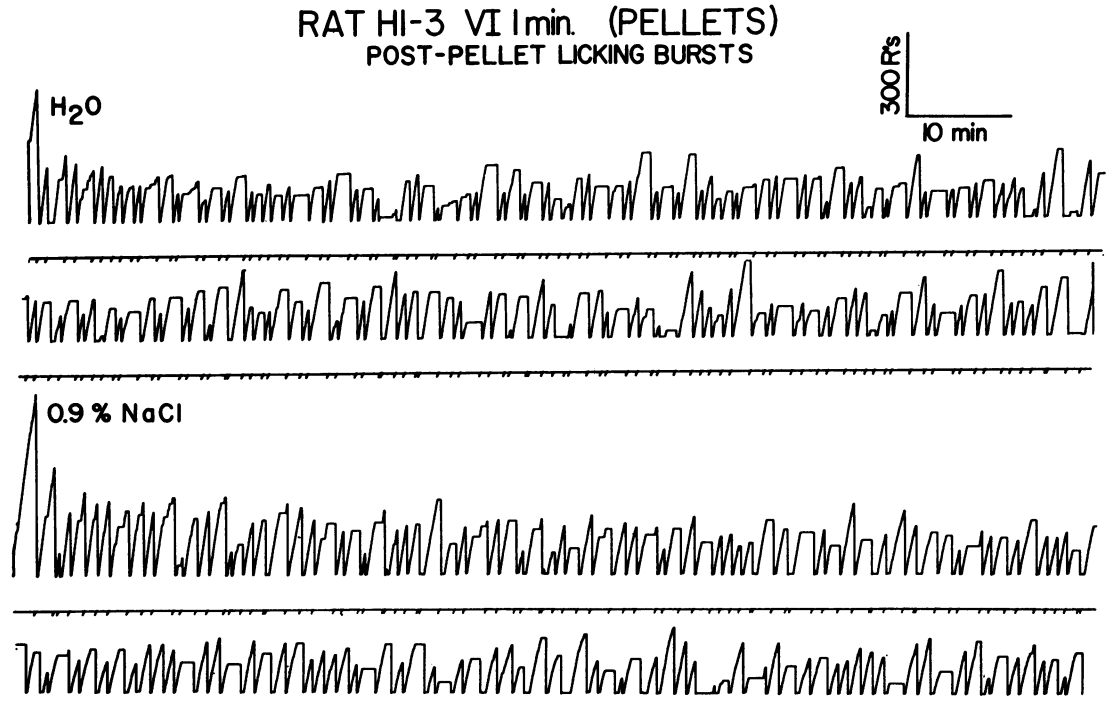

Fig. 6. Rat HI-3. Post-pellet licking bursts for representative water session and session with 0.9% NaCl available. Pellet delivery resets recorder and marks event channel. Licks step recorder vertically.

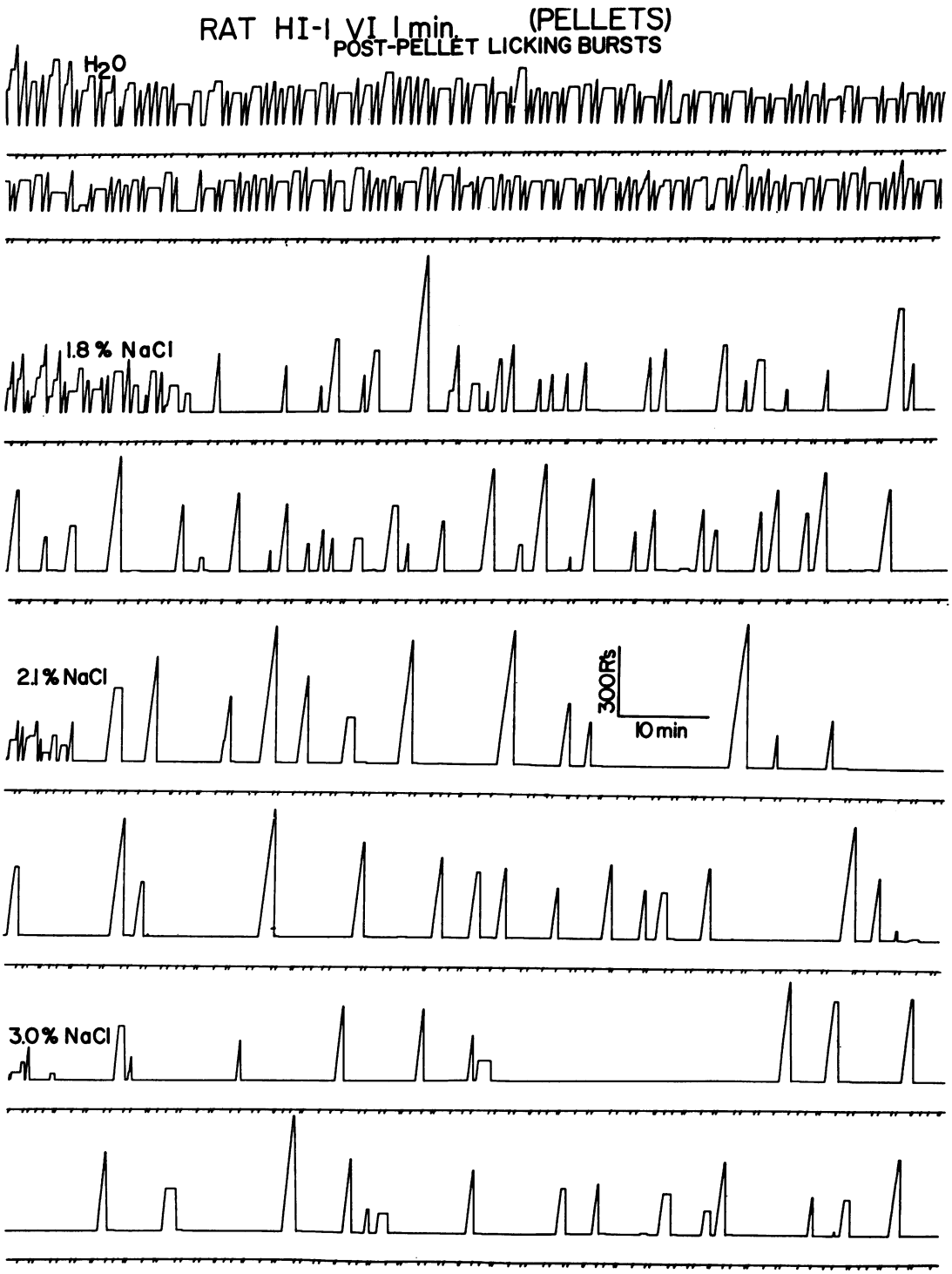

Fig. 7. Rat HI-1. Post-pellet licking bursts for representative water session and three most hypertonic NaCl solutions.

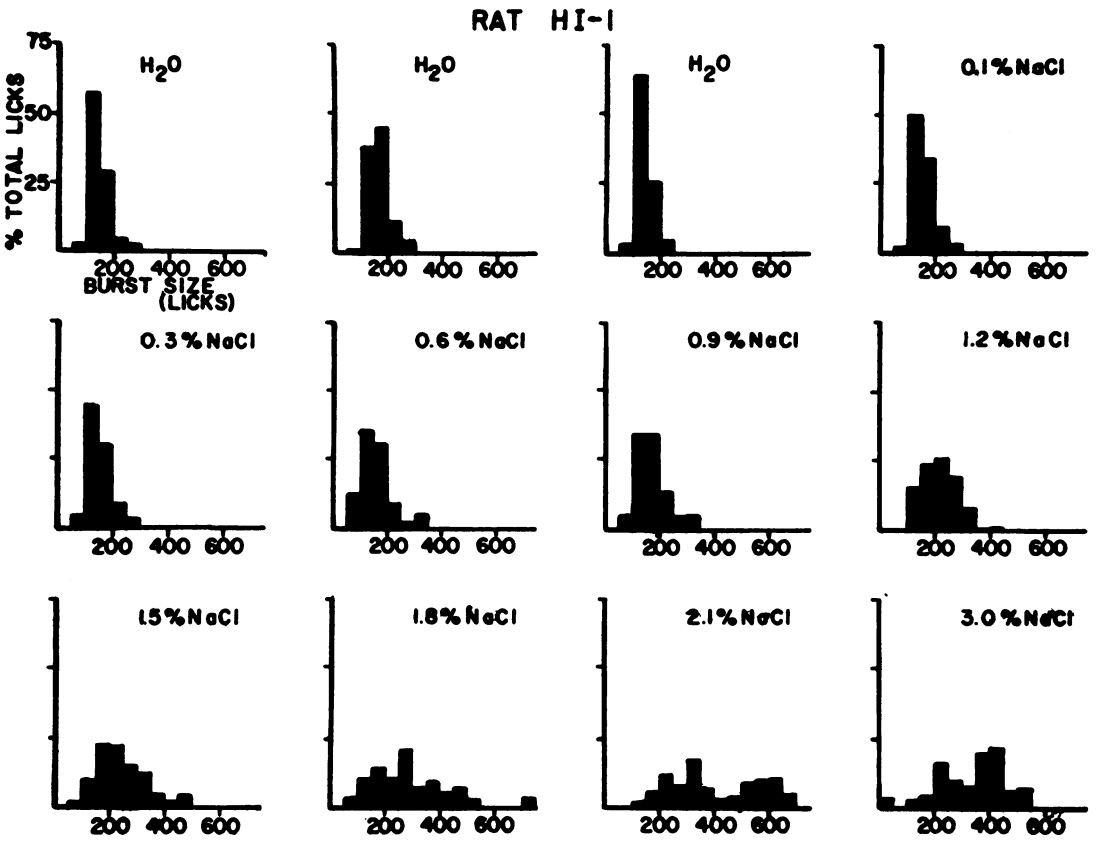

Fig. 8. Rat HI-1. Percentage of total licks falling within various burst-size categories as a function of NaCl concentration.

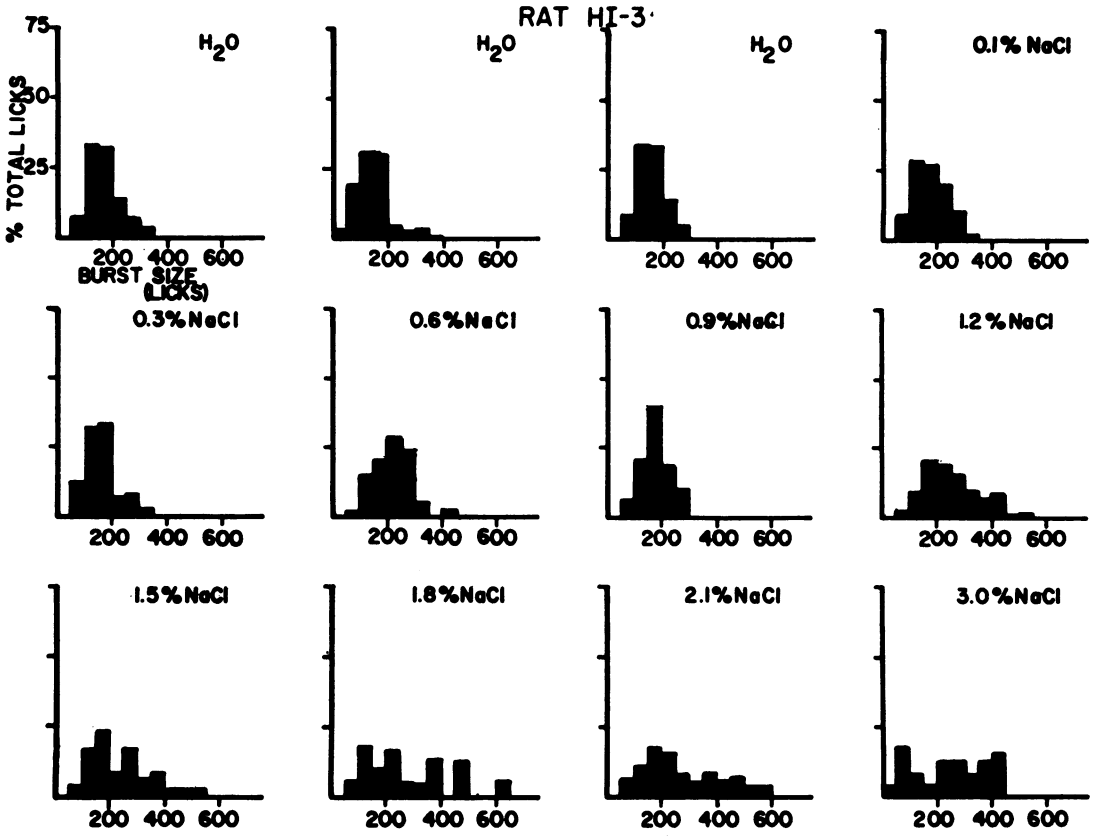

Fig. 9. Rat HI-3. Percentage of total licks falling within various burst-size categories as a function of NaCl concentration.

physiol. Psychol., 1963, **56**, 337-342.

O'Kelly, L. I. The effect of preloads of water and sodium chloride on voluntary water intake in thirsty rats. *J. comp. physiol. Psychol.*, 1954, **47**, 7-13.

Titlebaum, L. F., Falk, J. L., and Mayer, J. Altered acceptance and rejection of NaCl in rats with diabetes insipidus. *Amer. J. Physiol.*, 1960, **199**, 22-24.

Weiner, I. H. and Stellar, E. Salt preference of the rat determined by a single-stimulus method. *J. comp. physiol. Psychol.*, 1951, **44**, 394-401.

Young, P. T. Palatability versus appetite as determinants of the critical concentrations of sucrose and sodium chloride. *Comp. Psychol. Monogr.*, 1949, **19**, 1-44.

Young, P. T. and Falk, J. L. The relative acceptability of sodium chloride as a function of concentration and water need. *J. comp. physiol. Psychol.*, 1956, **49**, 569-575.

Received June 11, 1965