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Twenty-Four-Hour Free-Feeding Patterns of Dogs Eating Dry Food

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RASHOTTE, M. E., J. C. SMITH, T. AUSTIN, C. POLLITZ, T. W. CASTONGUAY AND L. JONSSON. *Twenty-four-hour free-feeding patterns of dogs eating dry food.* NEUROSCI BIOBEHAV REV 8(2) 205–210, 1984.—In order to provide some detailed information on the feeding behavior of freely-feeding dogs, four adult beagles were maintained in an isolated outdoor environment where food and water were freely available. Observations across an 8-month period indicated that the dogs ate episodically (in "meals") and that the total daily intake of food and water changed as the observation period progressed, most likely as a consequence of change in the ambient environmental conditions across seasons. Within-day changes in ambient temperature, and the timing of daily maintenance activities in the animal's runs influenced the temporal distribution of meals with the day.

24-Hour free-feeding Environmental influences on feeding Temperature effects on feeding Meal-analysis Dogs

THE feeding behavior of many species living in laboratory settings where food and water are freely available has been described. These descriptive data provide a baseline for experimental interventions which can help identify variables that influence both the regulation of food/water intake and the daily distribution of feeding activities (e.g., [1, 3, 5]).

There is only fragmentary information about the feeding behavior of dogs in free-feeding circumstances, and the findings are sometimes in conflict. The evidence is that free-feeding dogs eat episodically (in "meals") across the day [4,6] and that the pattern of meal activity is not greatly affected by the type of food available [4]. Feeding is primarily a diurnal activity [4]. Drinking and eating normally co-occur, but can be disassociated experimentally [6]. Free-feeding dogs appear to regulate caloric intake in some cases (whereas deprived dogs are more likely to be influenced by taste than by calories [2]). But, very sizeable individual differences in regulation are reported in other cases [4].

The present paper describes the feeding behavior of freely-feeding dogs in greater detail than has been reported in the past. Beagles were maintained in an isolated outdoors environment where food and water were continuously available. The dogs' feeding activities were quantified during several observation periods across 8-months which included rather substantial seasonally related changes in ambient weather conditions, particularly in temperature, humidity and light-cycle. The same diet was available in all observation periods. The data we obtained indicate that environmental variables have an important influence on the intake of food and water, and on the distrubiton of feeding activities across the day.

METHOD

Subjects

Four purebred male beagles, 3 to 5 years old, were used. Their weights averaged 11.8 kg (range 10.4–13 kg) at the beginning of the observation period.

Apparatus

Side-by-side runs housed the dogs individually in an open-roof laboratory on top of a 4-story research building on The Florida State University campus. This area was topped by a screen roof that allowed visual access to the sky overhead, and muted auditory stimulation from the daily pattern of campus activity at ground level outside the building. Because the laboratory was open in this way, the animals were exposed to the normal 24-hour light-dark cycle and to weather conditions. The runs were constructed of chain-link fencing, providing a floor area 193 by 102 cm, and were situated so that the dogs could easily see and hear each other. A sheltered area, located at the back of each run, offered protection from ambient weather conditions. The front wall of each run had three rectangular openings (17 by 19 cm) through which the dog could put its head in order to eat or drink from pans (15 by 13.5 by 15 cm) behind the wall. The pans were mounted in separate tunnel-feeder enclosures designed to accomodate the dog's head comfortably and to detect the dog's contact with the contents of each pan by means of an infrared photo-beam just above each pan's surface. The duration of contact with the food (water), and the temporal distribution of eating episodes across the daily observation period, could be quantified by analysis of strip-

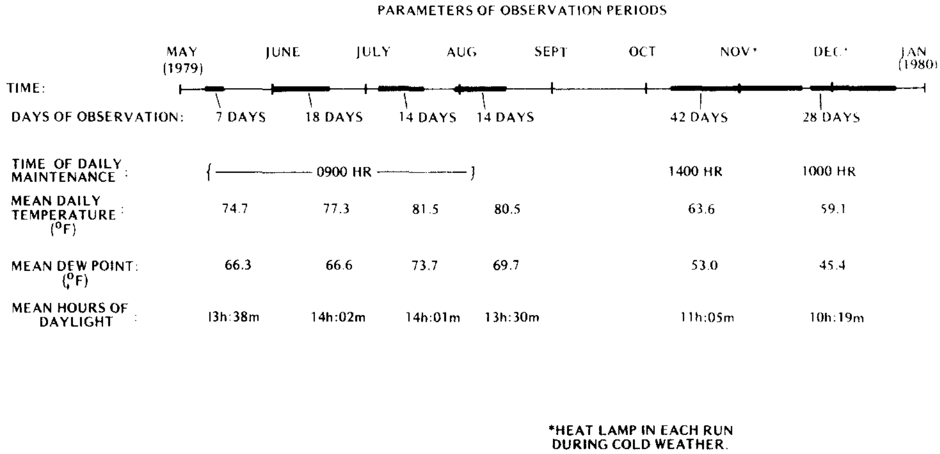

FIG. 1. Parameters of observation periods during the study (see text).

chart records which marked the interruptions of photobeams on a continously running record (1-foot per hour chart speed).

Procedure

The dogs lived in the runs during May through December of 1979 when the observations were made. Eating and drinking by the dog was quantified for the various numbers of consecutive days shown by heavy shading on the "Time" line at the top of Fig 1. The dogs were free to eat and drink at any time for 23-hr per day. During this time, the laboratory was completely restricted from human traffic to preclude interference with the dogs' own activities. The remaining hour each day was reserved for maintenance (weighing food and dogs, refilling food pans, cage cleaning) and human-dog interactions. The same laboratory personnel carried out these operations throughout the observation period.

Figure 1 indicates that in the May through mid-October period the time of daily maintenace was scheduled in the early daylight hours (at 0900 hr). To provide some information about the effects of the maintenance operations on the distribution of the dogs' daily feeding activities, the time of the maintenance hour was varied beginning in mid-October—first to early afternoon (1400 hr), then back to the early morning (1000 hr, about the same absolute time after dawn as was the case earlier in the year when maintenace was at 0900 hr). These maintenance manipulations are summarized in Fig. 1, which also includes parameters of the ambient weather conditions and the natural light-dark cycle for the observation periods as determined by measurements made at a National Weather Service office located near the laboratory.

Two of the three ports in each run contained a commercially available kibbled dry dog food (caloric value=331 kcal/100 g). Pans in the left and right ports were filled once a day with more food than the dog would eat (800 g per pan), and the center pan was filled with water (2000 ml). The dogs' feeding behavior was quantified by means of two kinds of measures. Each day, the weight of food and of water remaining in the pans was measured during the maintenance period. Total amount consumed was then computed by subtracting these weights from the previous day's "starting" weights. Second, the strip-chart records were analysed to quantify sustained periods of eating (i.e., "meals").

A meal was scored as being initiated whenever the photobeam over a food pan was interrupted for 30 consecutive seconds, or when at least two shorter beam breaks occurred in a 30-sec period. A meal was scored as having ended when the food-pan beam ceased to be interrupted for at least 10 consecutive minutes. No distinction was made between the two food pans in scoring meals, so that the dog could switch from one pan to the other without affecting the scoring. In some of the data we distinguish between "short meals" (2-min or less in duration) and "long meals" (more than 2-min). The meal criterion used here resulted in a negligible proportion of the photobeam breaks being discarded from consideration.

RESULTS

Across the eight-month period of this study, all dogs increased body weight a small amount (less then 10%). It is not possible to distinguish whether this weight-increase was related to normal growth, the free-feeding maintenance schedule we used here, seasonally related changes in body weight, or these and other factors possibly operating in combination.

The mean daily intakes of food and water, as measured by the day-to-day weights of food/water in the pans at the maintenance hour, were computed for each dog over six separate groups of days. These six time-periods are represented in Fig. 1 by heavy inking on the "Time" line. In the data presentations these time-periods are referred to as May–June (two separate periods of 7 and 18 days, respectively), July (14 days), August (14 days), October–November (42 days), and November–December (28 days). The mean daily temperature was also computed for each of these time periods: the temperatures across all 24 hours of the day were averaged to yield a single temperature for each day; then, these single temperatures were averaged across the days in each time period. The resulting averages are presented in Fig. 1 (see row labelled "Mean Daily Temperature").

In Fig. 2, the food and water intake data during the six time periods are plotted for each dog as a function of the mean daily temperature. The relationship between intake and temperature is quantified in two ways in the figure. Correlation coefficients are shown for individual dogs, and lines of best fit are drawn for all the data in each panel. These descriptive statistics indicate that the average amount of

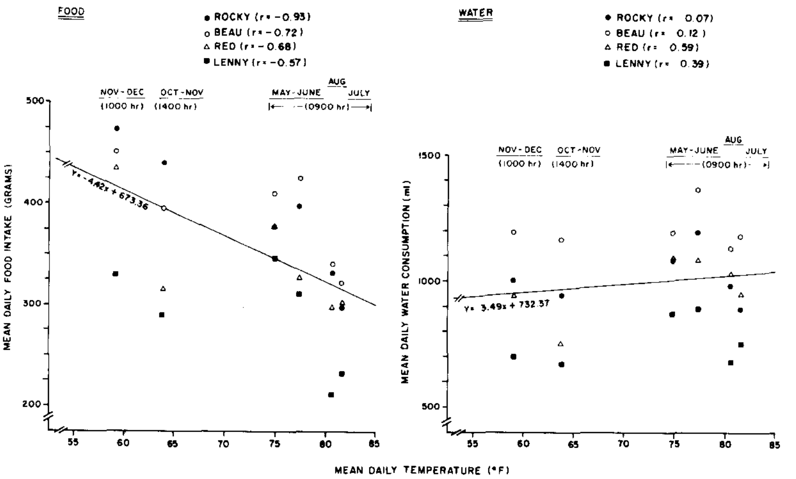

FIG. 2. Scatterplot of mean daily food—(left panel) and water—(right panel) intake by individual dogs in the six observation periods as a function of the mean daily temperature during these observation periods. Correlation coefficients are shown for each dog. A line of best fit is shown for the data points in each panel.

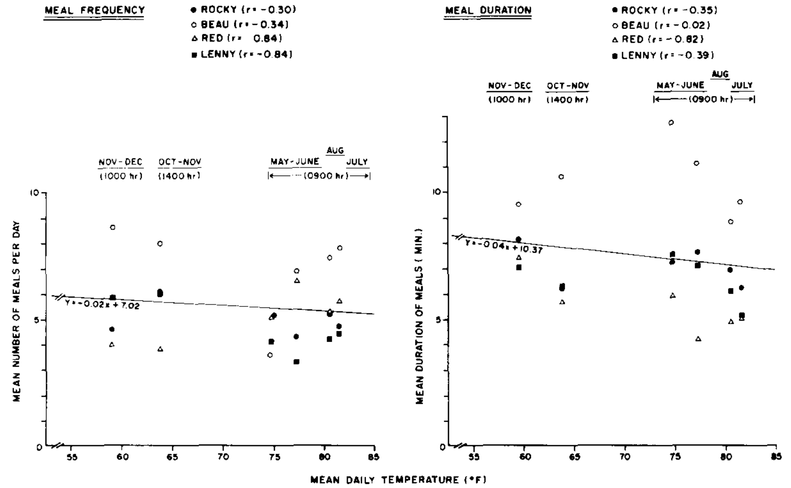

FIG. 3. Mean number (left panel) and duration (right panel) of meals per day plotted as a function of the average daily temperature in each observation period. (See caption for Fig. 2).

food eaten per day was negatively related to the average daily temperature, and that the average amount of water drunk per day was positively, but less strongly, related to temperature in two of the dogs ("Red" and "Lenny"). The correlation coefficients relating water-intake and temperature approximated zero for the other dogs.

The average number of meals eaten per day, and the average duration of these meals, was computed across the same six time periods for each dog. Figure 3 presents the resulting data plotted as a function of the average daily temperature in these periods. The meal frequency data indicate that meal frequency was negatively related to temperature in three of the four dogs. The other dog ("Red") showed a strong positive relation between meal frequency and temperature (r=.84). At most, the absolute amount of change in meal frequency was about 2 meals/day. Meal duration was negatively related to temperature in three of the four dogs; for "Beau," there was no relation between the two measures. The strongest relationships are for the dog "Red," who increased meal frequency but decreased meal duration as the temperature increased from about 60 to 80 degrees. The dog "Lenny," strongly decreased meal frequency and, to a far lesser extent, meal duration.

The temporal patterning of the dogs' feeding activity across the day is summarized in Fig. 4. Each data point in this figure was computed by first totalling the number of meals eaten by all four dogs together during a period of days, and then expressing the total number of meals that occurred in each hour as a percentage of the total meals consumed. In scoring the occurrence of meals per hour, we observed the convention that a meal started in one hour and carried through to the next was scored only once (i.e., as having

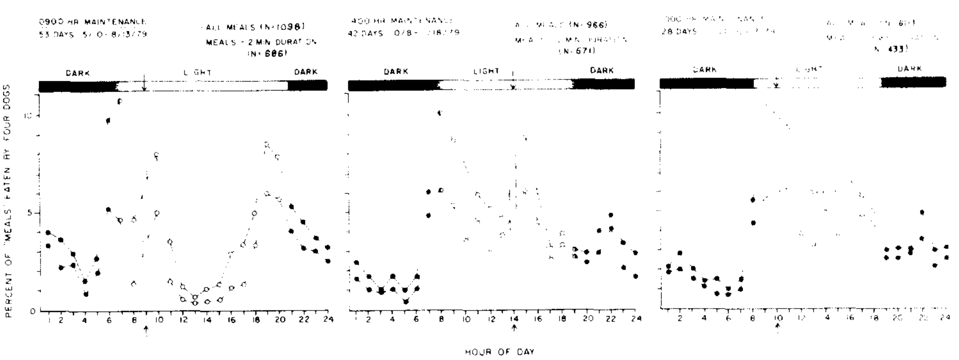

FIG. 4. Distribution of feeding activity across the day in observation periods corresponding to different times of daily maintenance and in different portions of the year. Feeding in the light part of the daily light-dark cycle is indicated by the open-circle data points (and is also marked by the clear bar at the top of each panel). Feeding in the dark part of the daily cycle is marked by closed-circle data points (and also by darkened shading in the bar at the top of the panel). The hour at which daily maintenance was carried out is marked by an arrow. (See text for further detail.)

occurred in the hour when it was initiated). Two data points are plotted for each hour in Fig. 4. One shows the percent of all meals eaten in each hour; the other shows only the long-duration meals (only those ≥2-min duration) in each hour expressed as a percent of the total meals eaten in the day. The long-duration meals comprised about 66% of all meals and averaged 11.23 min in duration (range: 6.7 to 20.2 min). These long-duration meal data seem to represent sustained eating periods, although we acknowledge that our "meal" data are derived from an analysis of photobeam interruptions in the tunnel-feeder rather than on the basis of direct observations of feeding behavior. Over the observation periods of the present study, the average duration of "short" meals (i.e., <2-min) was 0.57 min (range: 0.33 to 0.97 min).

In Fig. 4, the data were computed and plotted separately for three portions of the observation periods. The left-hand panel shows the 53 days comprising the May–June, the July and the August observation periods combined. The middle panel shows the 42-day period in October–November, and the right-hand panel shows the final 28 days in November–December (see "Time" line of Fig. 1). These three data plots correspond to the three different times at which the daily maintenance hour occurred, 0900 hr, 1400 hr and 1000 hr and were chosen for the data presentation here to highlight the effects of maintenance activities on the daily pattern of feeding. Of course, the three maintenance times were confounded with changes in a variety of other factors (temperature, photo-period, etc.) which may interact with, or even override, any effects of the timing of the daily maintenance.

Consider, first, the pattern of eating shown in the left panel of Fig. 4 when the daily maintenance activities were conducted from 0900 hr to 1000 hr each day. In this time, the dogs were most likely to eat near sunrise, after daily maintenance and near sunset. Eating in the early afternoon was particularly unlikely. The shapes of all-meal and of the large-meal curves of eating across the day are essentially similar. The pattern of eating shown here raises several questions which we attempted to answer in the remaining observation periods. One possibility we assessed was whether the tri-modal pattern of daily feeding activity found here reflects an endogenous rhythmicity in feeding or whether it is influenced by the timing of environmental events during the day. In particular, we attempted to distinguish whether the relatively high likelihood of feeding in the post-maintenance hour was a consequence of the maintenance activities, and whether the peaks of eating activity near dawn and dusk, and the trough of activity near midday, were influenced by within-day changes in temperature.

The center panel of Fig. 4 shows the distribution of daily feeding activities when the maintenance hour was moved to early afternoon, and at a time of year when the average daily temperature was about 15 degrees lower than was the case in the left-hand panel. These data indicate an increase in feeding activity near dawn, followed by decrease in activity across the next few hours, and an increase in activity in the post-maintenance hour. The data do not show the pronounced increase in activity near sunset, nor the pronounced trough of activity near midday that were evident in the left-hand panel of Fig. 4. Rather, there is now a small peak in the dark at 2200 hr, and the likelihood of eating remains relatively high across the daylight and early dark hours. The right-hand panel shows meal data when the maintenace hour was moved back to the early morning time and when the average daily temperature was about 4-degrees lower than in the middle panel (see Fig. 1). The pattern of within-day feeding activity continued to display a pronounced dawn increase. But, following what may be a modest post-maintenance eating effect, there was no evidence of either the midday-trough or the dusk-increase in eating which had characterized the daily feeding activity in the left-hand panel of Fig. 4. In fact, the pattern in the right-hand panel is reasonably similar to that in the center panel.

On the whole, the data in Fig. 4 suggest that the dog's daily pattern of feeding activity is likely to increase both with the coming of daylight and following a period of maintenance, during which food is not available, interaction is possible with humans, and food in the feeding pans is refreshed. The depression of feeding activity in the midday period seems likely to be a temperature-related effect since temperatures at midday were very high during the May–August period when the depression was evident in the data but much more moderate in the later months. The increase in feeding activity seen near dusk in the hottest months is probably related to the resumption of feeding when the midday temperature moderated, rather than indicating a particularly strong tendency to eat near sunset. We note that there was

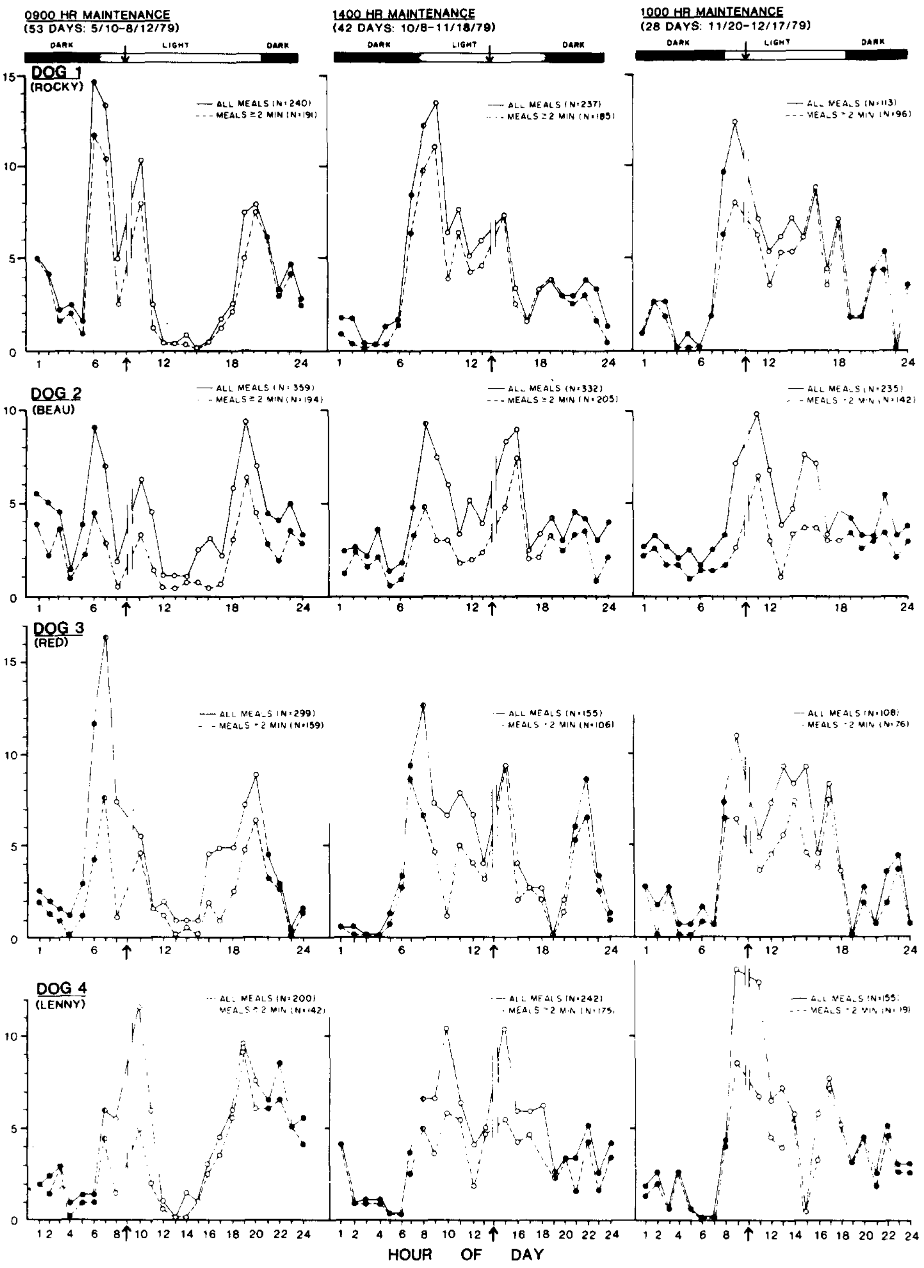

FIG. 5. Distributions of feeding activity across the day for individual dogs. (See caption of Fig. 4.)

an increased tendency for the dogs to eat near the old maintenance hour whenever the timing of the maintenance activities was initially shifted. This effect cannot be seen in the middle panel which is based on the average of 42 days of data, but it can still be seen in the right-hand panel which is based on only 28 days of data (see increase in large-meals at 1400 hr). The group data shown in Fig. 4 reflect the behavior of the individual animals in this study reasonably well, as the reader can judge from separate data presentations for the four dogs shown in Fig. 5.

There are some other aspects of the data that will be noted in brief. One is that the strip-chart records indicated that water consumption occupied very little time and tended to be prandial (see also [9]). Second, there was a moderate tendency, at best, for the dogs to eat simultaneously. Finally, correlations between inter-meal interval and meal duration were highly variable both across dogs and within-dogs across the three times at which maintenance conditions were scheduled in this experiment.

DISCUSSION

The data presented here indicate that certain environmental variables play an important role in influencing some aspects of the dog's feeding behavior.

Both the amount of food and water consumed per day, and the timing of feeding activities across the 24-hour day, seemed influenced by seasonally related changes in the ambient environment. In particular, we found that the amount of food eaten per day was negatively related to the average daily temperature level as it varied across the 8-month period of the study, and we found that the amount of water drunk per day was positively related to temperature in some dogs. Also, the likelihood that the dogs would eat in the daylight hours was greatly reduced during the hottest hours of the day in the summer months. In the moderate Fall months, however, the likelihood of eating was relatively constant across the daylight hours. This latter result is in agreement with an earlier report that the likelihood of dogs eating is more or less constant across the daylight hours [4]. It is not possible to determine from that report whether the dogs were housed in moderate temperature conditions. In the present study, the dogs showed a pronounced increase in the likelihood of feeding near dawn in all seasons, a finding which represents another environmental influence in the free-feeding situation. In the present data there were sizable individual differences among the dogs in the relationship between meal frequency or meal duration and temperature.

The dogs' free-feeding behavior also seemed influenced by the daily maintenance activity. In most dogs, the likelihood of eating was relatively high for a time following the daily maintenance hour. This effect was obtained when maintenance occurred early in the daylight hours and when it occurred about $^2/_3$ of the way through the daylight period. During maintenance, the dogs were handled by the laboratory personnel and often were housed together in a large group cage while their runs were being cleaned. They had no access to food during this time. On being returned to their runs they found the food supply replenished (it was never exhausted prior to maintenance). While it is possible that the one-hour period without food heightens a deprivation state which the animals redress by eating upon return to their runs, it seems likely that the post-maintenance eating we observed is at least partly determined by the presence of new food ([1], for similar effects in other species).

Finally, we note that the dog showed only a small increase in body weight across the 8-month period of this study. The observed increases may reflect seasonally related changes in weight rather than a failure to regulate caloric intake. We did not observe weight increases of the magnitude reported in beagles by Mugford [4] when he shifted them from a fixed-amount feeding regime to free-feeding.

The present paper provides information about the free-feeding behavior of beagles which suggests the need for further experimental analysis. For example, it would be important to study the dog's feeding behavior when there is a "cost" imposed on obtaining access to the food. The dog might be required to perform a lever-pressing response several times in order to make the tunnel-feeder available. By varying the cost of feeding in this way, it is possible to simulate various conditions of resource availability and thereby to document the dog's manner of adjusting to limited food. Such studies with other species have provided much valuable information about the determinants of feeding behavior [1]. It would also be valuable to follow up Mugford's [4] preliminary data with dogs on the question of how free-feeding behavior is influenced by diets with different taste and caloric properties, as has been done with profit in other species (e.g., [7]). It would be most desirable, however, to conduct such work was apparatus that allows fine-grained measurements of feeding behavior in all eating episodes (cf., [8,9]). Such fine-grained measurement of eating and drinking would greatly improve the quality of the moment-by-moment feeding data we have reported here which were based on photobeam breaks in the tunnel-feeders.

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