A FEEDOMETER FOR THE PIGEON¹

H. PHILIP ZEIGLER AND ROBERT FELDSTEIN

CITY COLLEGE OF THE CITY UNIVERSITY OF NEW YORK
AND SCIENTIFIC PROTOTYPE MFG. CORP.

The analysis of mechanisms underlying hunger and thirst in mammals has been aided considerably by the development of techniques for the continuous monitoring of feeding and drinking behavior (*e.g.*, Hill and Stellar, 1951; Le Magnen and Tallon, 1966). The apparatus described here may be used either as a pigeon feeder or as a feedometer for the automatic recording of free-feeding behavior. It was designed to provide several days supply of food, to insure a continuous flow of grain into the feeding compartment and to minimize spillage. When used as a feedometer, the pigeon's feeding responses interrupt a light beam across the food, triggering a photocell circuit whose output may be connected to response counters and event recorders. A modification of the device may also be used in a free-operant conditioning situation and permits independent measurement of key-pecking and feeding responses.

Design

Schematic diagrams of the feedometer are shown in Fig. 1a, b, c. It is constructed of 0.25 in. (0.64 cm) Plexiglas with a hinged top to prevent soiling of the food. A continuous flow of grain from the magazine is achieved by the use of a curved food guide and two angled guides that direct fresh food into the feeding compartment as the bird empties it. The bottom edge of the opening through which the pigeon gains access to the food is located 3 in. (7.6 cm) above the bottom of the feeding compartment. This insures that any grain

picked up but not eaten falls back into the feeding compartment.

To function satisfactorily as a feedometer, it is essential that all feeding responses be directed into the path of the photocell beam so that each peck at the food interrupts it. The two most critical features of the design are the size and placement of the access aperture directly above and parallel with the food and the location of the light beam with respect to the aperture. The aperture must be narrow enough to direct all responses into a restricted portion of the feeding compartment, while the beam must be so placed that it will be interrupted even by small excursions of the beak during feeding.

The access aperture is formed by a rectangle of Plexiglas, 3.75 by 0.5 in. (9.5 by 1.27 cm), placed along the inside edge of the feeding compartment, just above the level of the food opposite the curved food guide, to delimit a slot-like aperture 0.125 wide by 3.75 in. (1.59 by 19.5 cm) long. This aperture restricts feeding to a narrow central area of the food compartment. The light source and photocell are mounted so that the center of the light beam is parallel to this aperture, 0.5 in. (1.27 cm) above the level of the food. Leads from the photocell and light source are connected to a three-pin female socket, and a male socket and three-wire cable are used to connect the device to a photodetector control system whose output, in turn, may be used to drive counters and recorders.

The optical system consists of a recessed incandescent lamp (Sylvania No. 48ESB) providing a narrow-angle, low-illumination beam, filtered to provide an output limited to the red and near infra-red region. The photocell is a red-sensitive photoresistor (Clairex CL 703L) with a Kodak 87 filter. Interruption of the light beam during feeding raises the resistance of the photocell.

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Fig. 1. Schematic diagrams of the food magazine indicating the location of the photocell and lamp when the device is used as a feedometer (1 in. = 2.54 cm).

The photodetector control system (Fig.2) includes a difference amplifier with a regulated voltage reference and an adjustable current source for the photocell. The amplifier senses voltage changes across the photodetector produced by variations in illumination. A

sensitivity control in the circuit allows compensation for differences between individual photocells. A reed relay pulse-former accepts the output of the difference amplifier and provides an output to an electromechanical counter as well as an isolated, spark-suppressed

food consumed. A solution to this problem has been to use a single, fairly nutritive grain such as corn or milo on weekdays, when feedometer data are being recorded, and a more varied supplementary diet on weekends.

In Fig. 3, daily food intake in grams and the number of feedometer responses are plotted for a single representative bird over a three-week period of continuous observation. No data were taken on weekends, so that the data points for Days 7, 14, and 21 represent a period from Friday evening to Monday morning. In general, a close correspondence between variations in intake and variations in feedometer responses is evident in the data of individual birds. To obtain a more precise estimate of the extent to which feedometer responses accurately reflect food intake under free-feeding conditions, the number of responses and the amounts of food consumed each day were recorded daily in a group of 10 birds over a three-week period. Spearman rank-order correlations between daily intake (grams) and number of feedometer responses were calculated for each bird. The individual correla-

tions ranged from +0.99 to +0.74 and with one exception ($p < 0.05$) all the correlations are significant at or beyond the 1% level.

The feedometer may also be used to obtain a measure of the pigeons's feeding efficiency by calculating the number of feeding responses required to obtain a unit quantity of food. Examination of the three-grain feed mixture used showed that it contains, on the average, 25 to 30 individual grains per gram. Furthermore, analysis of cinematographic records of pigeon feeding behavior indicates that the bird obtains only one grain for each pecking response. Thus, when feeding most efficiently, a minimal feedometer/food ratio of about 30 responses per gram of food might be expected.

Table 1 presents data on the variability of feedometer/food ratios for individual birds under a variety of testing situations. These ratios are based on five successive days of observation and specify, for a given bird, the mean number of feedometer responses made for each gram of food consumed. The data in column 1 were obtained from birds maintained on a three-grain mixture containing

Fig. 3. Daily food intake and feedometer responses in a single pigeon over three weeks of observation. Data points for Days 7, 14, and 21 represent totals for the preceding three days.

Table 1

Individual variability in the ratio of feedometer responses to food intake under various conditions of monitoring food intake.

Group 1 Grain mixture			Group 2 Single grain			Group 3 Skinner Box Magazine		
Bird No.	Mean	S.D.	Bird No.	Mean	S.D.	Bird No.	Mean	S.D.
1	148	21.0	136	61	14.6	137	33.6	4.1
3	249	43.0	138	68	13.6	139	27.2	1.3
9	335	86.0	140	64	23.4	202	32.9	6.1
40	120	17.4	130	58	9.6	133	30.6	6.0
42	108	15.1	132	40	5.4	135	32.4	1.8

milo, vetch, and hempseed; column 2 presents comparable data for a second group of birds maintained on a single grain (milo). The presence of sorting behavior in Group 1 elevates the ratios considerably above their possible optimal values, while the use of a single grain in Group 2 decreases both the size of the ratios and the differences between the ratios of individual birds. The data in column 3 represent mean ratios obtained with the three-grain mixture in the food magazine of an operant response box during a 6-sec reinforcement interval over five successive days of observation. Under these conditions, the ratios closely approximate their minimal possible values.

In addition to its use in the automatic monitoring of daily food intake under free-feeding conditions (Zeigler, Green, and Lehrer, *in press*), the feedometer may be used to provide a quantitative measure of consummatory behavior in a variety of experimental situations. Figure 4 presents cumulative records of feeding behavior and food intake in a single pigeon tested successively at 90%, 80%, and 70% of its free-feeding body weight. The data were obtained in 1-hr test sessions during which feedometer responses were recorded on both a response counter and a cumulative recorder. For a group of 12 birds tested in this manner, the Spearman rank-order correlation between intake and number of feeding responses recorded was +0.92 ($p < 0.01$).

A modification of the feedometer has also been used in a free-operant conditioning situation in order to dissociate lesion effects upon food-reinforced key pecking from their effects upon the feeding response itself. To provide a measure of consummatory behavior independent of the key-pecking response, a photocell and lamp were mounted in the feeding compartment of a standard operant condition-

ing chamber for the pigeon. The device was used in conjunction with a Lehigh Valley solenoid-operated pigeon feeder, and the photocell and lamp were mounted so that the beam was located 0.5 in. (1.27 cm) above the level of food. The lamp was illuminated only during the reinforcement interval and served as both a magazine light and a light source for the photocell. Feeding responses made during the reinforcement interval were amplified by the photodetector circuit and recorded on a cumulative response counter; key pecking

Fig. 4. Cumulative feeding responses recorded in 1-hr test sessions for a single bird at 90%, 80%, and 70% of its free-feeding body weight.

was recorded in the conventional manner. It was thus possible to obtain for each test session independent measures of the amount of food eaten, the number of feeding responses, the number of key-pecking responses and the number of reinforcements delivered.

This procedure has been used in a study of the differential effects of trigeminal nerve section upon feeding behavior and food-reinforced key pecking in the pigeon. Because of their central connections (Zeigler and Witkovsky, 1968), section of the sensory branches of the trigeminal nerve disrupts the pigeon's feeding behavior by interfering with the sensory feedback involved in mandibulation, the process by which food is moved from the tip of the beak to the back of the mouth before swallowing. After nerve sections, birds have been observed to peck normally and to swallow food placed manually at the back of their mouth, but they have difficulty in mandibulating their food. Kernels of grain are repeatedly picked up, held at the tip of the back and then dropped. Deficits in mandibulation may be expected to increase the number of feeding responses required to obtain a unit quantity

of grain, so that the feedometer/food ratio provides an excellent measure of such deficits.

Figure 5 presents data on a single representative bird whose key pecking was reinforced on a variable-interval schedule. The bird was subjected, successively, to unilateral and bilateral section of the sensory branches of the trigeminal nerve. After the unilateral section, key pecking is not markedly affected, although there is a decline in food intake. The slight rise in the feedometer/food ratios suggests that this decline is caused by a deficit in mandibulation so that the bird obtains less food in each 6-sec reinforcement interval. The effect is more striking in the bilateral condition. Immediately after section of the remaining sensory branches of the contralateral beak, key-pecking is maintained at close to its preoperative level but gradually declines over the next few days. Inspection of food intake values and of the feedometer/food ratios indicates that while the pigeon is making a great many feeding responses, it is getting no food. (In effect, the pigeon is exhibiting extinction in the presence of the reinforcer.) As some recovery in mandibulation takes place, it is paralleled by

Fig. 5. Use of the feedometer in a free-operant conditioning situation: the effects of trigeminal nerve section upon food intake, operant key-pecking responses, and the ratio of feeding responses to food intake. (VI 1-min).

a gradual increase in the rate of key pecking, at which point further testing of this bird was discontinued.

A number of feedometers have been in use in our laboratory for more than a year during which time they have functioned reliably. Such breakdowns as do occur are likely to be mechanical in nature, involving loose or broken contacts leading from the lamp or photocell or in the connecting cables. Although it is wise to readjust the sensitivity control daily, the photocell circuit seems quite stable and insensitive to variations in ambient illumination.

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