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AUTOMATED PREFERENCE TESTING APPARATUS FOR RATING PALATABILITY OF FOODS[1]

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An electronic preference testing apparatus is described for measuring taste preference of rodents and other small animals with solid or liquid foods. The apparatus is designed on the principle of the two-choice, preference technique. It operates photoelectrically with a sequence of presentations so that whenever a subject eats from a compartmentalized food tray, a standard and a test food are each briefly sampled alone before both foods are presented together (in alternate positions) for preference determination. Preferences are automatically recorded on digital counters. The apparatus is built in two modules (a preference tester and the master control) connected by multiconductor cable. The modular design provides portability and isolation of the animals from the major noise-producing components. Diagrams of the apparatus are given, and test results from a trial that evaluated positional bias and a sucrose-concentration preference experiment are presented to demonstrate its application in research.

There is a need in the field of rodent control for knowledge of the preference of rodents for a broad range of taste stimuli in solid food. While there is a large volume of literature (Pangborn and Trabue, 1967) on the electrophysiological and behavioral aspects of taste perception in laboratory rats, most of it pertains to liquid media containing simple stimuli such as sugar and sodium chloride, and consequently is of little value in rodent control programs.

As a basis for obtaining knowledge to formulate palatable bait carriers, an electronic preference testing apparatus was designed and built for rapid and sensitive evaluation of candidate taste and flavor additives. The apparatus is based on the principle of the brief-exposure, foods-together technique described by Young and Kappauf (1962). By this technique, the test animal is given a traditional, two-choice situation; however, the animal briefly samples each food alone, in alternate sequence, before the two foods are presented together, in alternate positions. Alternating the sequence and positions in which the foods are presented minimizes both temporal and spatial positional habits. Young (1967) stated that brief-exposure preference tests are best because they yield a cross section of relative levels of acceptability at the time a test is made, and importantly, before postingestion factors influence the result. The foods-together principle has been used to rate the palatability of liquid foods by Young (1967, 1966, 1945), Young and Madsen (1963), Young and Greene (1953), and Christensen (1962). Their methods are applicable to measuring preference in solid foods by the apparatus described here.

APPARATUS

The instrumentation system is composed of two modules, the preference tester (Module 1) and the master control relay logic and photocell amplifiers (Module 2). The modules are interconnected by a multi-conductor cable.

A cutaway view of Module 1 is shown in Fig. 1. The module is placed in the test animal's cage when a preference determination is to be made. Basically, it consists of a compartmentalized, circular, food tray; two 0.25 in. (6.4-mm diameter) photobeams with receivers; a reversible motor; a gear drive system; and a limit switch to control the positioning of the tray (Fig. 3). These components are enclosed in a 4-mm thick Plexglas box. The front panel of

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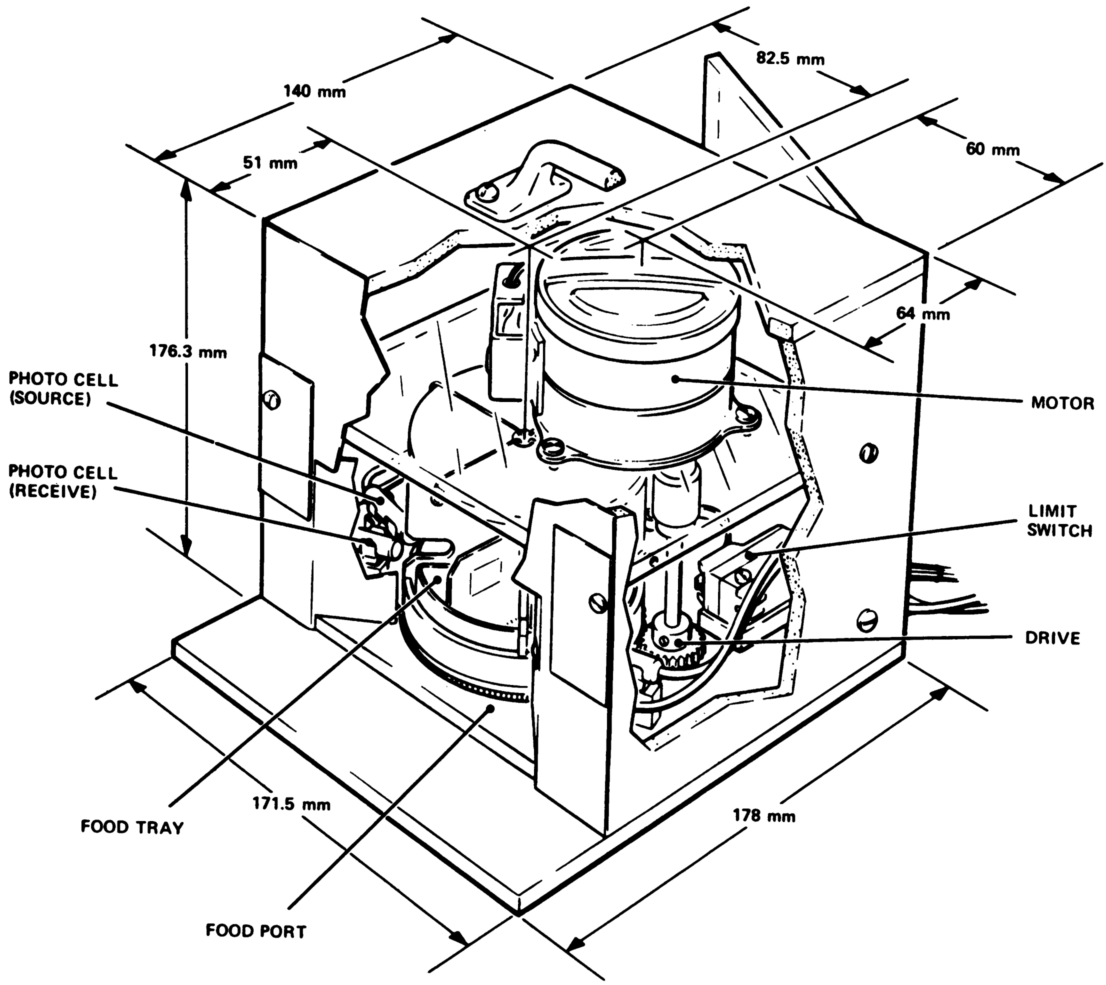

Fig. 1. Cutaway view of the two-choice foods-together preference tester module.

the box has a stainless steel covering and a 2 by 2.75 in. (50.8 by 69.9 mm) food port.

The food tray is removable and is 3 in. (75 mm) in diameter and 3.5 in. (82 mm) in overall height. Plexiglas, 3 mm thick, is used to construct the tray. Near the food port, a small ring of Plexiglas is attached to the floor of the module. This serves as a guide so that the tray can be placed in the same position after it has been removed. The construction of the food tray from bottom to top is as follows: (1) a ring of Plexiglas that prevents the test subject from tipping the entire food tray; (2) a Boston Gear Model Y 48144, whose shaft box fits into the ring on the floor; (3) a solid Plexiglas plate that serves as the floor of the food compartments; (4) a ring of Plexiglas, 15 mm high and 3 mm wide, which is the outer wall of the food compartments; (5) two Plexiglas dividers, 63 mm high, interlock and divide the tray into quarters; and (6) a Plexiglas top that is grooved and cemented to the two dividers adding to the stability of the tray. An 8 by 6 mm notch is cut in the Plexiglas dividers 42 mm from the top of the tray to permit the light beams to shine through. A removable cup, fabricated from a stainless steel sheet, was designed to fit each quarter section of the food tray (Fig. 2). The cups are 20 mm deep, which reduces spillage to a negligible factor. Two of the cups are partitioned by the same type of stainless steel sheet, 38 mm high with polished surfaces. This partition serves as the light reflector in the foods-together position (Fig. 3), and prevents cross contamination between the two foods being tested.

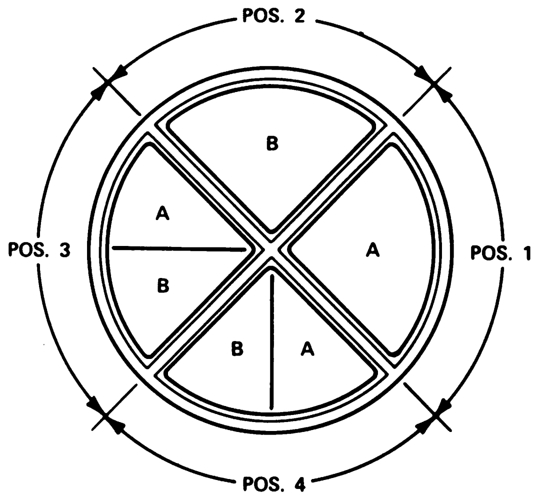

Fig. 2. Preference tester food tray showing removable cups in each position.

Mounted on either side of the food tray are an Elesta Model LS 601 white light source and an Elesta Model LS 602 receiver (Fig. 3). Each light source is received by the opposite receiver in Positions 1 and 2. In Positions 3 and 4, each light source is reflected off the polished steel position into the adjacent receiver. Whenever a test subject eats from the food containers, the photobeam is interrupted, producing a voltage change that is amplified and results in a relay closure in Module 2.

A Hurst Synchronous Motor Model PCDA, with a positive clutch and an instantaneous brake is mounted on a Plexiglas shelf 76.2 mm from the top of Module 1 (Fig. 1). An 82.6-mm steel shaft is connected to the shaft box of the reversible motor with a small Boston Gear Model Y 4842 on the opposite end. A Robert Shaw Model BRD2-LW8 limit switch controls the degree of rotation of the food tray. When the Plexiglas divider in the food tray moves the limit switch arm, the tray is stopped.

A multiconductor cable connects Module 1 to the photocell amplifiers and the scheduling logic (Module 2). It contains four digital counters to record (1) the number of preferences for food A; (2) accumulated time in food A (tenths of seconds); (3) accumulated time in food B (tenths of seconds); and (4) the total number of choices in Positions 3 and 4. Two criterion counters control the countdown time in Positions 3 and 4, and a 0 to 15 sec timer controls a preset time in Positions 1 and 2. We had previously used a 1 Hz time base for Positions 3 and 4, but found that the test subject could move its head in and out of the photobeam without breaking the photocell circuit. The time base used is 10 Hz, which provides the readouts on the digital counters 2 and 3 mentioned above. The relay logic is also contained in this box.

The A and B cups in positions 3 and 4 (foods-together positions) each hold about 6 mm^2, and cups A and B in Positions 1 and 2 (foods-alone positions) each hold approximately 12 mm^2. Before a preference determination is made, animals are trained to eat from the preference tester. To determine preference, one food is weighed and placed in each of the three A compartments and an equal amount of the second food in each of the three B compartments. One food serves as a "standard" and the other as a "test" food. The preference tester is then placed in the animal's cage in Position 1, along with a supply of drinking water. In this position, only food A is visible and accessible to the animal. The tester is scheduled so that the food tray rotates in the following sequence (Fig. 2):

Position 1	Position 2	Position 3	Position 2	Position 1
A	B	A – B	B	A
Position 4	**Position 1** (starting point for next cycle)			
B – A	A			

At a preset time after the test animal approaches the food port and starts eating (breaking the photobeam), the tray rotates to Position 2, withdrawing food A and presenting food B. A preset time after the animal samples food B, the tray rotates to Position 3, where both foods are presented together (A left, B right). When the animal has eaten either food for the total amount of time preset on the two criterion counters in Module 2, the tray rotates back to Position 2 and the cycle continues according to the sequence shown in the diagram.

The amounts of time spent eating food A and food B in the foods-together positions are summed by digital counters in Module 2. The number of qualitative preferences for food A or food B in the foods-together positions (*i.e.,* the number of criterion counter "count downs" in the A cups) and the number of food-choice presentations are also summed by digital counters in Module 2. At the end of the testing period, Module 1 is transferred from the holding cage and the food tray removed. The uneaten food in each cup of Positions 3 and 4 is

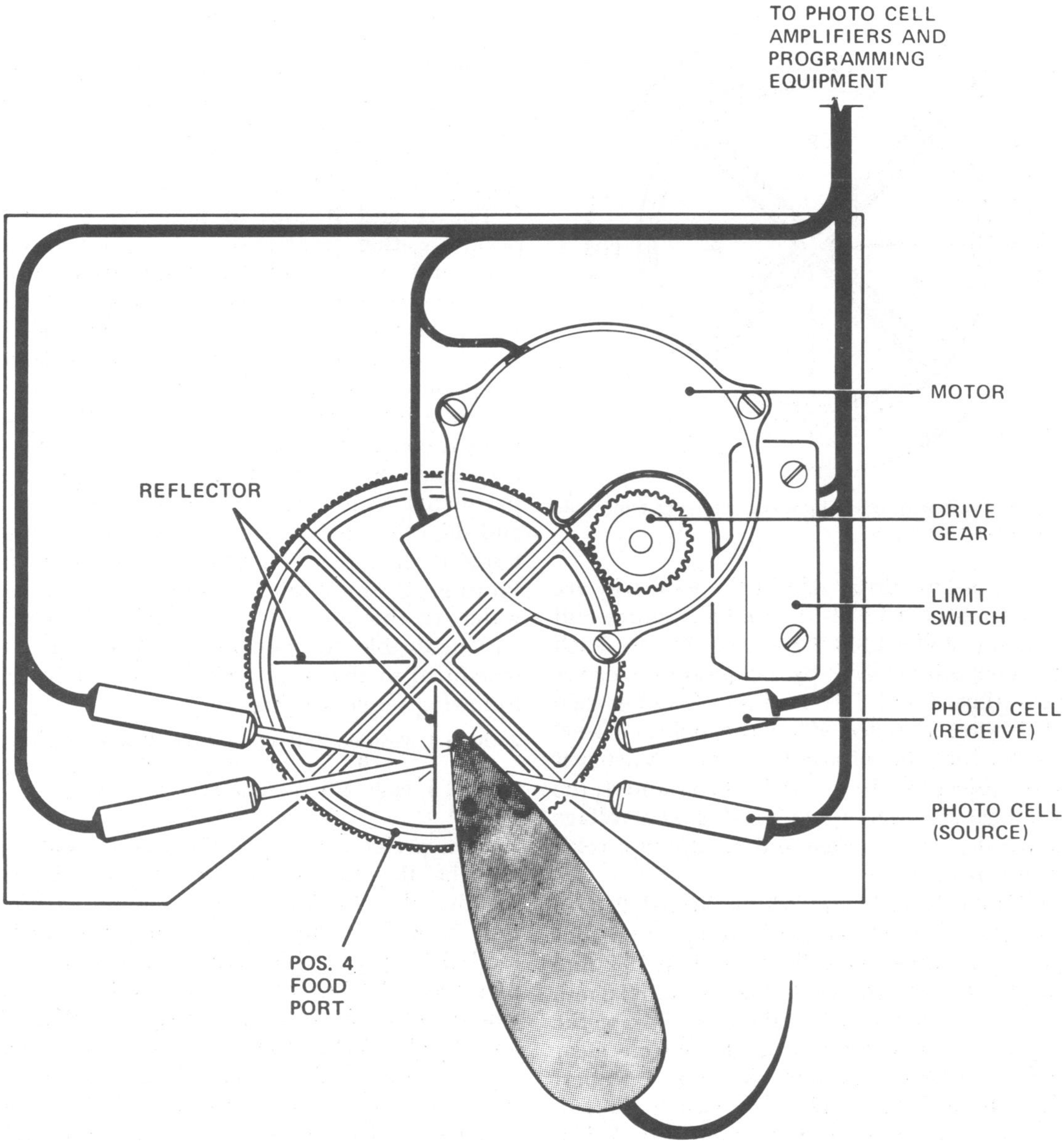

Fig. 3. Overhead view of preference tester module showing rat breaking the photobeam in the foods-together position.

weighed. All cups are removed from the tray holder and cleaned after each test.

Preference ratings are determined for each animal on the basis of food consumption or eating time by formulae 1 and 2:

$$\text{Consumption preference (\%)} = \frac{\text{Amount of test food consumed}}{\text{Total food consumed}} \times 100 \qquad (1)$$

$$\text{Eating time preference (\%)} = \frac{\text{Time spent eating test food}}{\text{Total eating time}} \times 100 \qquad (2)$$

Preference ratings calculated by these formulae may range between 0% and 100%. Test stimuli with preference ratings less or greater than 50% are classified as negative and positive respectively. Stimuli with preference ratings of 50% are considered equal to the standard.

Positional Bias

An experiment was conducted with 38 non-deprived Long-Evans black-hooded rats to measure preference ratings for the A cups in

Position 3 and 4 when all cups contained the same food. In each test, 1.25 g of 50-mg wheat pellets were placed in each of the six food-tray cups and each animal allowed sixteen 6-sec choices. Each test was replicated twice. Preference ratings were calculated by pairing the test results of each double compartment (AB, BA) on alternate animals. This was done because in regular preference experiments in which foods in the A and B cups are different, the location of each food is reversed for alternate animals to minimize any bias that might result from visual cues. Analysis by the t-test revealed there was no significant difference between replicates ($t = 1.098$; df 36). Preference ratings for the A cups averaged 51 $\pm 1\%$ when based on eating time and 50.8 $\pm 1\%$ when based on consumption. These are negligible deviations from the expected 50% preference rating. Therefore, it appears that the apparatus does not promote a positional bias.

The preference ratings based on consumption and eating time were significantly correlated ($P = <0.01$; $r = 0.49$; 36 df), which indicates that either could be used in measuring the palatability of foods. However, since the rat can interrupt the photobeam without actually eating the food, we believe the preference rating based on consumption is more reliable.

Sucrose Preference Scale

Preferences for different concentrations of sucrose in a solid medium were determined (Fig. 4) with the preference testing apparatus. Preference values are based on two replications from five, black-hooded rats when each was given ten 6-sec choices between a standard (50% sucrose by weight in a physiological inert cellulose product[2]) and each of 11 other concentrations of sucrose, ranging from 0% to 100%. The sequence of testing each sucrose level was randomized.

It is interesting to note that the rat's preference for sucrose appeared to increase linearly up to the peak level of 80% and then level off as sucrose concentrations increased. This finding is in general agreement with Young (1966), who showed that preference for liquid sucrose increases up to the saturation concentration, approximately 36%.

[2]Avicell is manufactured by FMC Corporation, Philadelphia, Pennsylvania. Reference to trade names does not imply endorsement of commercial products by the federal government.

DISCUSSION

The preference tester module weighs only 2.1 kg, which permits it to be moved easily from one animal's cage to another. Observations with the wild Norway rat have shown that the ability to conduct preference studies without having physically to handle the test animal is a distinct advantage in minimizing stress, especially when working with such wild species. On occasion, a wild Norway rat has died due to handling. The modular design of the apparatus also makes it possible to isolate the test animal from the main, noise-producing components in Module 2, which helps minimize the emotional effects associated with initial exposure to the test apparatus and, hence, reduces training time for preference experiments.

No explicit training is required because the food changes automatically when the rat eats. Test animals are introduced to the apparatus by putting the same food in all the compartments of the preference tester and placing it in their cage until they adapt to eating from the compartmentalized tray and to the slight turning sounds of the motor. Laboratory rodents usually adapt to eating from the food tray within two to five 30-min exposure periods without food deprivation.

Trained animals usually make twenty-five 6-sec choices within a 20- to 30-min test period, which is comparable to the number of choices used by Young and Madsen (1963) to determine food preference of rats. Results of the uniformity experiment indicate that animals do not exhibit a significant positional bias when eating from the apparatus, a feature that obviously increases the reliability of preference tests results.

While this instrumentation was designed to measure the preferences of rodents for a wide variety of taste and flavor additives in food, its usefulness is not limited to this particular application. For example, the sucrose preference index (Fig. 4) illustrates that it can be used in conjunction with the up-and-down psychophysical method (Dixon and Massey, 1957; Young, 1967) to determine sequentially the hedonic equivalence of taste stimuli. Although it was designed for rodents, there is no reason why it could not be used for other small mammals or, possibly, birds, or with liquid instead of solid media.

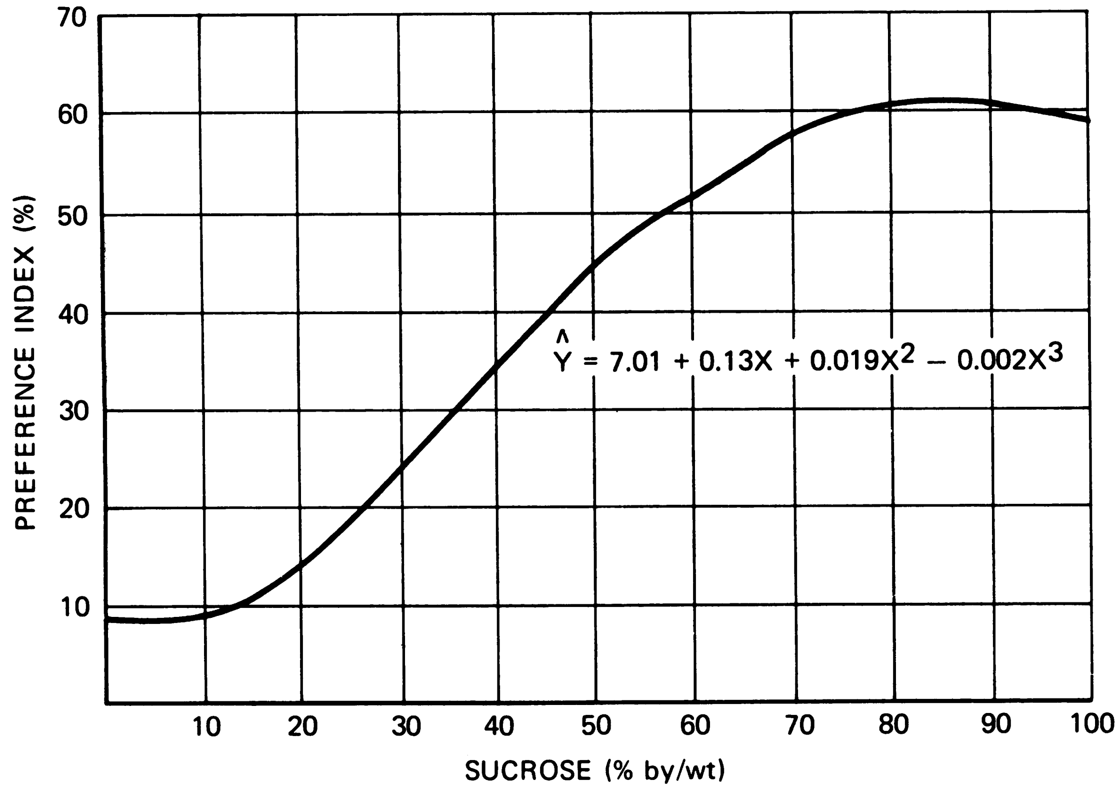

Fig. 4. Best-fitting preference equation for different concentrations of sucrose in Avicell. Data were obtained with rats by the two-choice, foods-together preference testing apparatus.

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