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We describe a portable apparatus designed to examine the free-operant food preferences of captive coyotes in their home kennels. Because leverpressing for food access was the dependent variable, we measured food preference independently of food ingestion. Using successive approximation, we trained 8 out of 19 coyotes (42%) to use the apparatus. This percentage is similar to training rates for dogs. We used fixed and variable ratio schedules of reinforcement to further test 4 of the trained coyotes. All 4 produced response curves similar to those of other species on similar schedules of reinforcement.

Species-selective attractants are important for the development of effective baits. Although the response of coyotes to odors has been described (Bullard, Turkowski, & Kilburn, 1983; Martin & Fagre, 1988; Phillips, Blom, & Engeman, 1990; Scrivner, Howard, & Teranishi, 1987; Turkowski, Popelka, & Bullard, 1983), there have been few studies reporting their responsiveness to taste stimuli (Beasom, 1974; Guthery & Meinzer, 1984).

The most common method to evaluate palatability is the two-bowl or two-bottle test (Ferrell, 1984a, 1984b; Griffin, Scott, & Cante, 1984; Smith, Rashotte, Austin, & Griffin, 1984). The principal disadvantage of such tests is that they confound acceptance (ingestion) with preference (choice).

Operant methods are one way to eliminate this problem (Pfaffmann, 1969). Specifically, animals are required to perform a behavior in order to obtain access to a food or fluid reinforcer. The extent to which animals exhibit the operant response can be taken as a measure of their likes and dislikes (Smith & Rashotte, 1978). Given the small amount of food or fluid obtained during any individual trial, operant methods minimize postingestive effects (e.g., satiety) on preference. Foods with different characteristics (e.g., different texture, moistness, or size) can be compared directly because the operant response (and not consumption) is the variable of interest (Rashotte & Smith, 1984).

Although operant devices have been used with dogs (Chao, 1984; Green & Rashotte, 1984; Rashotte, Foster, & Austin, 1984), they have not been portable and they tend to be designed specifically for studying beagles and other canids that are accustomed to being handled. Even when raised in captivity, coyotes are not easy to handle, and they exhibit strong and persistent neophobia of unfamiliar objects and new environments (Windberg, 1996); therefore, we designed a portable operant device for use with captive coyotes to address these problems.

Apparatus

The apparatus is depicted in Figures 1 and 2. The steel frame is 117.6 × 33.0 × 42.0 cm and contains three shelves. The lower shelf holds a battery pack and the middle shelf holds a laptop computer. The highest shelf (base plate) holds the food bin, control panel, and drive motor on top and the manipulandum (lever), activation switches, and food magazine on the bottom. An opening was cut in the base plate to allow kibbles in the food bin to fall into the magazine. The apparatus is equipped with wheels so that it can be rolled to designated locations.

A battery-powered, commercially available Micro 190 programmable logic controller (PLC, Eagle Signal Controls, Mark IV Industries, Part MX190A6) controls kibble delivery and test-session length. Using a PLC rather than a computer for this purpose eliminates the need for an interface card to connect the drive motor to the computer. The PLC has an on–off switch that controls the main power supply and a start–stop switch that resets the PLC.

An 8088 IBM-compatible laptop computer was used to program the PLC with symbolic relay language (SRL). Two SRL programs were written for use with the apparatus—one for use with fixed-ratio (FR) schedules of reinforcement and one for use with variable-ratio (VR) schedules of reinforcement. Responding on an FR schedule delivers a reinforcer after a set number of responses (e.g., reinforcement is delivered after six presses on an FR6 schedule). Conversely, responding on a VR schedule delivers a reinforcer after a mean number of responses (e.g., reinforcement is delivered after 6, 12, 8, and 14 responses during a VR10 schedule). The number of leverpresses required for a kibble to be delivered, the maximum number of kibbles delivered in a session, and

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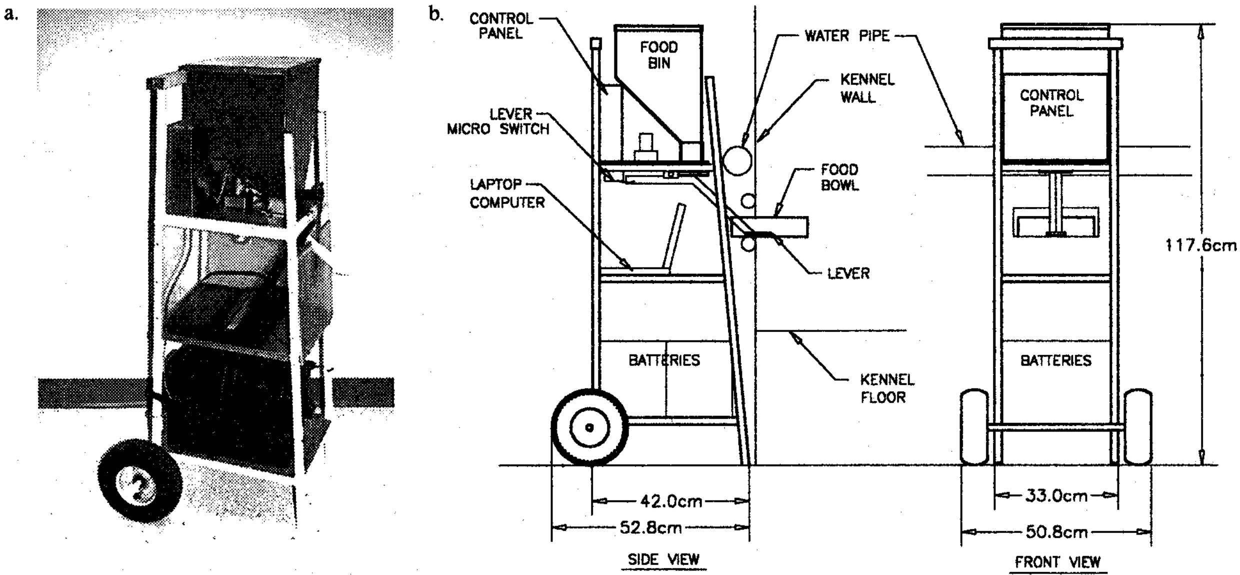

Figure 1. The apparatus. The frame and the lever were constructed of mild steel, whereas the remaining parts were constructed of aluminum. (a) Photograph. (b) Diagram of the apparatus in position. Locations of the control panel, lever and lever microswitch, food bin, laptop computer, and batteries. For reference and perspective, the kennel floor and front panel wall, water pipe, food bowl are shown, and basic measurements are provided.

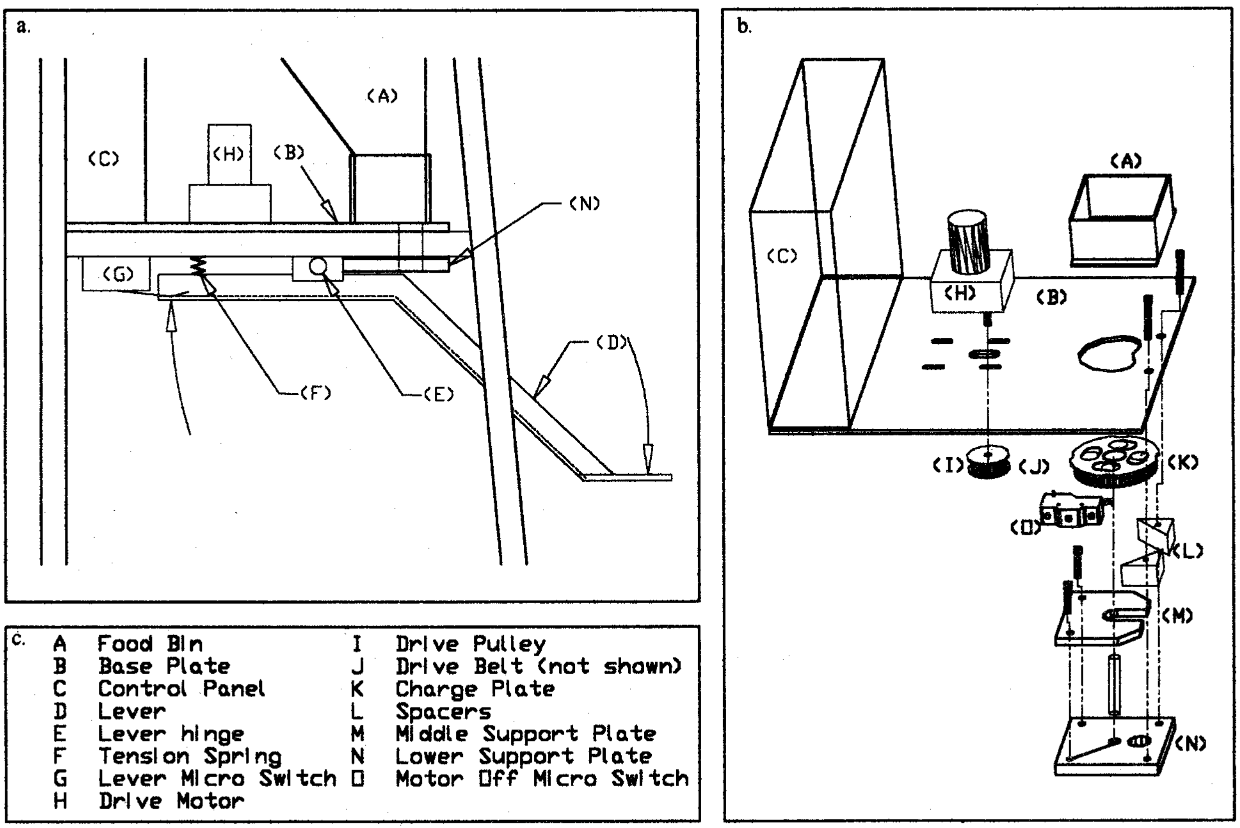

Figure 2. Detailed schematics of mechanisms; (a) lever, (b) magazine, and (c) figure legend.

the maximum duration of a session can be varied to meet the specific needs of experimental designs.

The device is designed so that a lever fits in a 5.1 × 3.8 cm notch in a kennel food bowl. The lever itself is an arm that runs along the underside of the base plate and then angles down into the food bowl (Figure 2a). It is made from two pieces of steel shaped into a V that directs a kibble down the lever and into the food bowl. A horizontal metal plate 5.0 × 5.0 cm is situated on the end of the lever to facilitate pressing. At the opposite end, a spring, placed between the lever and the base plate, creates tension and returns the lever to its original position after each press.

When a coyote presses the lever, a microswitch (Licon Co., Part 160XL025) is closed, which starts a count. Both SRL programs require that each leverpress be checked against an internal counter programmed into the PLC. If the number of presses equals the set point of the counter, the drive motor (Japan Servo Co., Ltd., Part 6G90H, No. 5F) will be activated. The motor rotates a drive pulley that pulls a drive belt, which then rotates a charge plate or disk in the magazine (Figure 2b). The disk has four 2-cm^2 holes through which 1.0 g, 1.1-cm-diam dry kibbles (Hill's Science Diet Active Maintenance Formula dog food) can drop. Three of the four holes are in direct contact with the kibbles in the food bin. The remaining hole is exposed to an opening over the lever. Each hole in the disk is tapered so that only one kibble at a time can enter a hole and drop onto the lever. When the disk rotates one quarter turn, a kibble drops and a second microswitch closes, which stops the motor and halts the motion of the disk.

A maximum of two kibbles can be delivered per second. Each time the disk rotates, a counter advances. This counter regulates the total number of times that the disk can be rotated and the total number of kibbles that can be delivered. For each leverpress, the date, time, number of presses (whether or not a kibble has been delivered), and the total number of kibbles delivered during the session are displayed on the computer screen and entered into a BASIC data file for subsequent analysis.

Example Application

Subjects. Nineteen coyotes (9 males, 10 females) at the Predation Ecology Field Station of the National Wildlife Research Center (Millville, UT) served as subjects. The animals were 1–5 years old; 6 were hand-raised, 11 were raised by their parents in captivity, and 2 were raised by their parents in the wild.

Methods and Results. For 1 week prior to training, the coyotes were provided ad lib access to a daily ration of Hill's Science Diet (400 kibbles, 242 g, 1,014 kcal) in their kennel food bowls. One day prior to the first test session (Day 8), and during all testing days, the subjects were fed 340 kibbles (85% of the full ration, 205.7 g, 861.9 kcal). For each subject, on the night prior to the first session, the apparatus was placed in front of its kennel overnight. During test sessions, the 340 kibbles were delivered to the subjects via the apparatus.

We selected the 85% level of deprivation on the basis of the literature and our particular testing situation. Typically, subjects in operant studies are kept at body weights of lower than 100% in order to increase the likelihood of operant behavior. This often starts at 80% body weight, but it can be increased as experience with the apparatus increases if subjects continue to show high levels of responding. Subjects are also weighed throughout a study to ensure that body weights remain consistent (Ferster & Skinner, 1957). In the present study, the subjects could not be handled easily. Therefore, we did not reduce the body weight of the subjects prior to the start of the study, and we did not periodically weigh them. Instead, during testing sessions that did not exceed 14 days, we provided a daily diet of 85% of the full ration. All animals were visually examined daily, and all were regularly examined by wildlife veterinarians employed by the Field Station. No animals were observed to suffer ill effects during the course of the study.

We used the method of successive approximations (Pierce & Epling, 1995) to shape each subject to approach and press the lever. During training, we remained in visual contact with the subjects and we manually operated the apparatus. This might have caused problems with some of the animals (see the Discussion section). No constraints were placed on responding topography (i.e., any press with any body part was reinforced). Response acquisition was considered to be accomplished when a subject pressed the lever consistently during a given FR1 session, or during any portion of a given FR1 session, within a 4-day training period.

Response acquisition was exhibited by 8 animals (4 males, 4 females), although the amount of training required varied among the subjects. Because no specific behavior was shaped, various responding topographies were exhibited. One subject first responded by biting the lever and then later shifted to pressing it with the left front foot; response acquisition for this subject required four sessions. Two other subjects pressed the lever with both front feet; one showed reliable responding during the first session (within 1 min) and the other after two sessions. (Reliable responding was considered to be accomplished when a subject pressed the lever at a consistent rate throughout a given session.)

Four coyotes (2 males, 2 females) that showed response acquisition were randomly selected for additional testing in which we used various FR and VR schedules of reinforcement. FR schedules followed a staircase progression of ascending and descending response requirements (e.g., 1, 10, 20, 30, 40, 50, 50, 40, 30, 20, 10, 1) and were applied once per day. VR schedules were randomized (e.g., 50, 40, 20, 10, 30) and were also applied once per day. During testing sessions, the apparatus controlled kibble delivery.

Between training and FR sessions and between FR and VR sessions, the subjects were fed 400 kibbles (100% of their daily ration) for a minimum of 14 days. One day prior to FR and VR sessions, and throughout testing, the subjects were fed 340 kibbles (85% of their daily ration). (See above for an explanation.) A maximum of 200 kibbles were delivered via the apparatus during testing. After testing, the remaining 140 kibbles plus any of the 200 kibbles not received during the session were provided ad lib to the subjects. This ad lib portion was intended to maintain some degree of hunger during testing. Daily sessions lasted a maximum of 30 min or until a subject received the maximum 200 kibbles from the apparatus.

All FR sessions were run between 0900 and 1830 h; all VR sessions were run between 1230 and 1830 h. The difference in test hours was due to the timing of other activities occurring in the kennel building.

We recorded the number of leverpresses per minute (press/min) for each session. The resulting response curves resembled typical response curves of other species on similar FR and VR schedules (Ferster & Skinner, 1957). Figure 3 shows the responding rates of 2 females on separate FR schedules. On the FR10 schedule, both showed a rate of response of approximately 60 press/min. When the schedule requirement was increased to FR40, their rates of response decreased; one exhibited a rate of 20 press/min, and the other showed a rate of 14 press/min.

We plotted rates of response for each session for each subject. For all subjects, rates decreased as schedule requirements increased. Figure 4a depicts a female and male on the FR schedules, and Figure 4b depicts a female and male on the VR schedules.

DISCUSSION

Eight of the 19 coyotes showed reliable responding (as defined in the Methods and Results section) during the 4-day training period. The remaining 11 coyotes exhibited persistent neophobia and refused to approach the apparatus. Although these subjects might have learned to use the apparatus with additional training, further training could not be continued because of overall time constraints. Casual observation suggests that the 8 animals that showed reliable response acquisition were also generally less likely to be disturbed by and more likely to adapt to changes in environmental stimuli prior to their participation in the experiment. Their behaviors remained consistent when they were presented with new stimuli (e.g., when a person entered the kennel or when a change in the kennel occurred). Otherwise, there were no obvious relationships between sex, age, or their rearing background (hand raised, raised in captivity by parents, or raised in the wild by parents) and the likelihood of response acquisition.

Although only 8 of the 19 (42%) subjects showed reliable response acquisition, this percentage is equivalent to the successful training rates for dogs in explosives and drug detection paradigms. We suspect that training success rates could be increased by selecting coyotes on the basis of their propensity to display neophobia; that is, some animals are far less affected by changes, such as in diet type or being moved from one kennel to another, than are other animals. Other strategies that might increase training success might include raising coyotes in the presence of the apparatus, leaving the apparatus at the kennel for several days prior to training, housing and training animals in isolation from extraneous stimulation (e.g., visual contact with the trainer) or, perhaps, by adding more training days.

More broadly, the apparatus described here can be helpful in addressing a variety of issues. For example, the relative importance of taste and caloric density on preference could be determined by using reinforcers that have the same taste but vary in caloric density, or that have the same caloric density but vary in taste. The influence of physiological state on preference could be explored by testing the same animals in various physiological states, such as during pregnancy or breeding. The

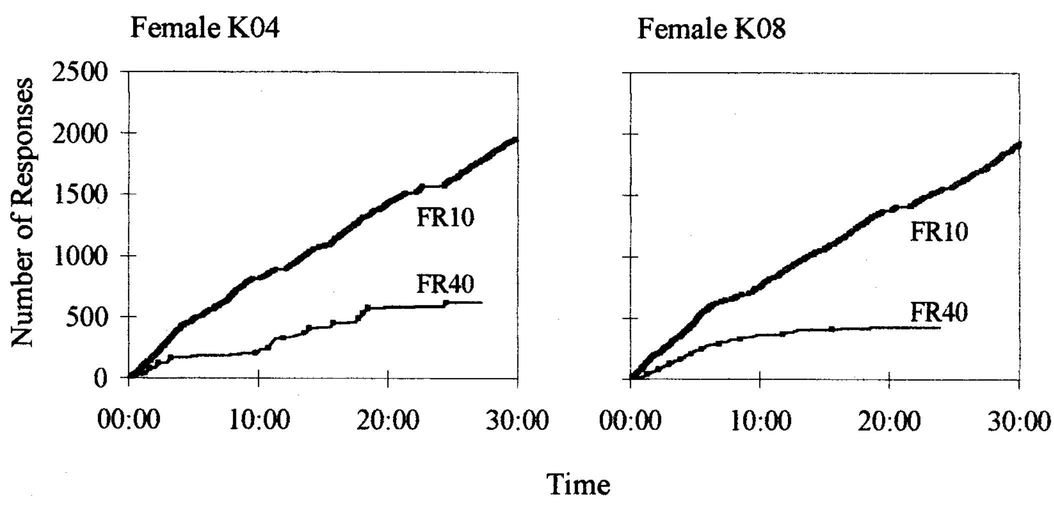

Figure 3. Number of responses plotted as a function of time for two coyotes in two FR schedules. Each square represents the presentation of a reinforcer.

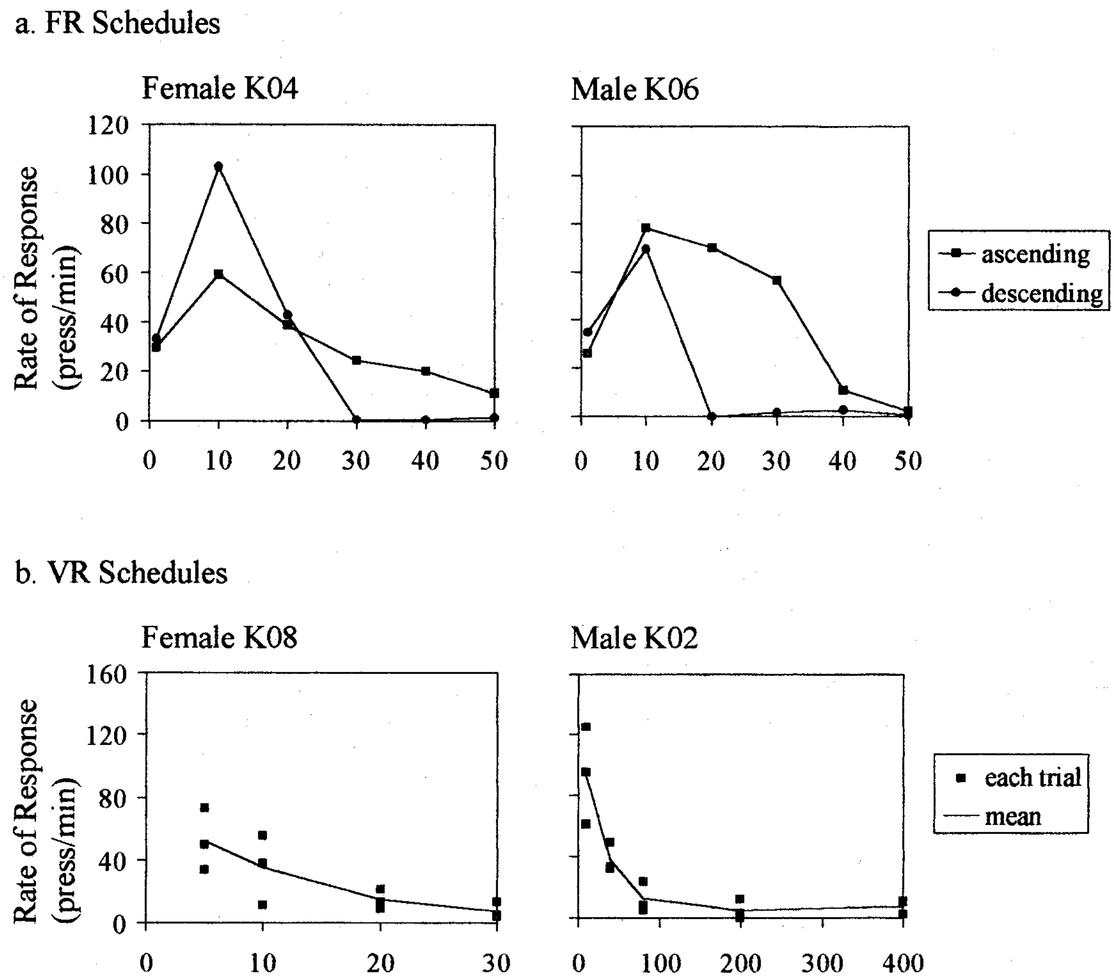

Figure 4. Rate of response (press/min) plotted as a function of the schedule. (a) FR schedules for two coyotes; squares represent the rate of response during a series of ascending FR schedules, circles represent the rate of response during a series of descending FR schedules. (b) VR schedules for 2 coyotes; each square represents the rate of response during an individual session. A curve was fit to the means.

effects of climactic and seasonal variations on preference could be tested by evaluating the same animals during various seasons. These sorts of questions could be answered by using timed trials (as was done here), extinction trials, or other testing methods. Information gained from these kinds of studies could help develop more effective baits for coyotes in the field.

On an ecological scale, the apparatus could be helpful in answering foraging theory questions; reinforcers could represent prey items, and responding could represent hunting efforts. For example, using two apparatuses concurrently with the same schedule of reinforcement but with different sizes, or kinds, of reinforcers could help explain hunting effort (rate of responding) for different prey items (reinforcers). Similar methods have been tested with dogs to measure their response rate with reinforcers of different tastes and sizes (Chao, 1984; Green & Rashotte, 1984). Effort spent hunting for prey items could be extrapolated from the amount of work expended during operant studies.

Finally, this apparatus has many advantages over those previously described (Chao, 1984; Green & Rashotte, 1984; Rashotte et al., 1984). Our apparatus is portable and, therefore, can be brought to the animal, making it easier to study animals that are difficult to handle. The apparatus is also sturdy, reliable, and relatively inexpensive, with parts and materials costing approximately $700 and labor requiring approximately 80 h. Finally, minor modifications (e.g., adjustment in the size of the apparatus or the lever, modification of the force required to press the lever, or substitution of reinforcers with different sizes, shapes, or nutritional values) could be made to test similar foraging theory questions relating to other carnivores, as well as those relating to omnivores and herbivores.

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