Operant Conditioning Methodology in the Assessment of Food Preferences: Introductory Comments

MICHAEL E. RASHotte AND JAMES C. SMITH

Department of Psychology, Florida State University, Tallahassee, FL 32306

RASHotte, M. E. AND J. C. SMITH. Operant conditioning methodology in the assessment of food preferences: Introductory comments. NEUROSCI BIOTEHAV REV 8(2) 211–215, 1984.—This paper provides a general introduction to the methodology used in the next three papers of this monograph to test dogs' food preferences. This “operant conditioning” methodology was developed in behavioral laboratories concerned with learning in animals. The logic of the methodology is described, some technical and practical aspects of the methodology are summarized, and its application in the hedonic-scaling of qualitatively different foods is discussed. The relation between this new methodology and the traditional two-bowl preference test is reviewed.

Operant conditioning Concurrent schedules Matching law Hedonic scaling Two-bowl tests

THE next three papers of this monograph employ a methodology for preference testing that is derived from behavioral research in animal learning. The present paper is intended as a general introduction for readers new to this methodology, and it includes some logical and procedural points that pertain to our applications.

OPERANT CONDITIONING: A BRIEF OVERVIEW

The traditional method for quantifying an animal’s preference for one food-item relative to another is the “two-bowl test” in which the animal chooses between eating from different bowls containing the two foods. This methodology was employed to study the preferences of puppies and adult dogs in earlier papers reported in this monograph [11,12]. In later papers, we investigate the relation between the way the traditional test performs in the laboratory and in the less-controlled home environment [14], and we explore some consequences of combining computer technology with this kind of test [30,31].

There are methodologies for assessing an animal’s preferences between foods which do not depend so heavily on the animal’s consummatory behavior. For example, it is possible to estimate the value an animal assigns to a food-item by measuring how hard the animal will work to obtain that item. The formal laboratory methodology developed to establish and to quantify behaviors that produce food-items is known as “instrumental reward training” and it began to be developed in America about the turn of the century [3]. B. F. Skinner’s name is most closely associated with one version of this methodology, “operant conditioning.” Skinner began this work as a way to quantify in an objective fashion the strength of animals’ motivation to eat [7].

The general idea behind the operant-conditioning method is to place a barrier between animal and food, and to require the animal to perform some response (such as pressing on a lever) in order to obtain a small portion of the food. Then, the animal is immediately free to continue lever-pressing in order to obtain another small food-portion, and so on, throughout the test session. Prior to the test, the animal is usually given only limited access to food in order to guarantee that it will respond well when tested.

The experimenter can impose a variety of requirements on lever-pressing that must be satisfied before food can be produced. For example, food may be produced only by those presses which occur after a given time-interval has passed, or by those presses which occur after a given number of presses has occurred. These requirements constitute what are called “operant schedules of reinforcement” (food is a “reinforcer” in the sense that it acts to “strengthen” the lever-press response). When properly applied, these schedules can produce a substantial amount of lever-pressing in a short test session, and quantitative measures of lever-pressing (e.g., rate of pressing) can be viewed (with some important restrictions, e.g., [10]) as reflecting the value of the food to the animal.

A feature of operant research that deserves note is that only a few animals are used in the typical study, and that they are repeatedly tested over a period of months or even years. Also, the conduct and the data-recording of the tests is usually highly automated. This reduces the likelihood that the experimenter will inadvertently influence the outcome of the test, and leaves him/her free to analyse the large amount of quantitative data produced.

CONCURRENT-SCHEDULES PROCEDURE

An operant methodology for quantifying an animal’s food
preferences is the concurrent-schedules procedure. To obtain food in this procedure, the animal must choose between responding on (usually) two operant schedules which intermittently provide small portions of food. In the typical case, the animal could obtain food on Schedule A by pressing on a response lever; food could be obtained on Schedule B by pressing on another lever nearby. The two schedules of food delivery would be available concurrently throughout the entire test-period, making it possible for the animal to switch from one lever-schedule pair to the other at any time. Since the typical test session provides small portion-sizes of food and only a fraction of the animal’s daily food requirement (it is given supplemental feeding), the animal’s actual consummatory behavior does not figure prominently in assessing preferences. Instead, the focus is on the relative frequency with which the two response-levers are pressed. The relative measures of lever pressing are used to estimate the relative value of the schedule-food combinations associated with each lever.

Research has been pressing for about 25 years with laboratory animals (such as rats and pigeons) performing on various concurrent schedules, and much is known about the determinants of performance in these test situations (e.g., [2, 10, 17, 24]). Two aspects of the work are most pertinent to the present discussion.

First, under some experimental conditions, there is considerable evidence that the values of relative measures of lever-pressing very nearly match the values of relative measures of the quantitative properties of foods that are actually obtained by lever-pressing. This match-up of relative behavior strength and relative food values seems to be particularly likely to occur when the two operant schedules arrange for the animal’s lever-pressing to produce food at unpredictable intervals (i.e., “variable-interval” schedules, where only the first response after variable intervals of time produces food).

Consider a hypothetical example in which an animal can obtain small portions of food by responding on levers associated with different variable-interval (VI) schedules. Suppose that Schedule A, associated with one lever, enables a press on that lever to produce food at unpredictable intervals, but every 30-sec on the average (i.e., VI 30-sec schedule); Schedule B, associated with the other lever, is similar in all respects except that it enables a press to produce food only every 60-sec on the average (VI 60-sec schedule). The same food, in the same portion-size, is available on each lever. After a period of adjustment to these schedules (usually several test sessions), the typical result is that a ratio of the number of presses made on the two levers in the test-session will very nearly match in value a ratio of the number of times the animal actually obtained food on each of the two schedules. This so-called matching law [18] is expressed:

$$R_A/(R_A + R_B) = F_A/(F_A + F_B)$$

where \(R_A\) and \(R_B\) represent the number of responses made in a test session on the levers associated with Schedules A and B, respectively; and where \(F_A\) and \(F_B\) represent the number of times the two schedules actually produced food for the animal in that test session.

Because the timing of the two VI schedules which enable the levers to produce food is done independently by separate clocks, the animal can maximize its overall rate of obtaining food in the test session by switching frequently from one schedule-lever combination to the other. The usual result is that the animal will press many hundreds of times on each lever during the test session, and the matching law specifies the way the aggregate of those presses will be distributed between the levers. In the example being considered here, where Schedule A is VI 30-sec and Schedule B is VI 60-sec, the animal can obtain food at twice the rate on Schedule A as it can on Schedule B. Assuming a level of responding (and of switching between the schedules) sufficient to obtain food whenever it is enabled on either lever, the animal would obtain twice as many food-portions from Schedule A as from Schedule B. In this case, the matching law asserts that the animal will make twice as many presses on the lever associated with Schedule A as it will make on the lever associated with Schedule B. Empirically, this is a common outcome [10], but certain systematic types of deviation from the matching relationship are also obtained in some circumstances (e.g., “undermatching”, [24]).

The second aspect of the basic work on concurrent schedules to be noted here concerns a procedural detail which affects the rate at which the animal switches from one lever to the other during the test session. If the animal is left completely free to switch over, a pattern of responding sometimes develops in which there is simple alternation from one lever to the other after a single press. To ensure that the animal will spend longer on each of the levers, and thereby be more likely to come under the influence of the schedule assigned to each lever, it is usual to impose a penalty on the animal following each switch. This penalty takes the form of a brief delay that begins with the first press after a switch-over, and which prevents any presses during the delay period from producing food. Of course, this so-called change-over delay (C.O.D.) would delay only a food-presentation that had been enabled on the switched-to lever prior to the switch, or during the period of the delay. If, for example, while the animal is pressing lever A food is enabled on lever B, a C.O.D. prevents the first response on B from producing food: only the first response after the delay period has passed will be effective. It is shown empirically that a short C.O.D. (e.g., 2-sec) ensures that alternation between the levers is maintained at a moderate level in typical laboratory animals. The C.O.D. is one procedural detail in concurrent-schedules tests that needs to be acknowledged in setting up the test and in interpreting the data [10].

In summary, conditions can be arranged with the concurrent-schedules procedure which ensure that animals will repeatedly sample the feeding opportunities provided by two concurrently running operant schedules. Under some of these conditions, it is commonly found that the animal will distribute its operant responding on the two response-levers in a way that approximately matches the distribution of the feeding opportunities it actually obtains from the two schedules. Of course, demonstrating that a specific pair of schedules (e.g., VI 30-sec vs. VI 60-sec in the example discussed here) yields a match between the behavior-ratio and the ratio of feeding opportunities obtained, does not speak to the possibility that matching occurs with other related schedule values. Consequently, in the typical “matching” experiment, several pairs of schedules would be run. For example, in addition to VI 30-sec vs. VI 60-sec, an experiment might include VI 45-sec vs. VI 45-sec (responding should be equally distributed between the two levers), VI 10-sec vs. VI 80-sec, and so on. This arrangement ensures that, at the end of testing, the value of the possible ratios of feeding opportunities will cover a wide range, and this makes
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it possible to determine the quantitative properties of a mathematical function relating several values of \( \frac{R_1}{R_2 + R_3} \) size to their corresponding values of \( \frac{F_1}{F_2 + F_3} \). Furthermore, each member of the pair of schedules would usually be assigned to each of the two levers at different times in testing so that the possibility of the animal having a side-bias towards responding more on one lever than on the other could be assessed empirically.

An example of the type of data which this sort of 'matching' experiment can yield is shown in Fig. 1. This plot is taken from Green and Rashotte [13] and represents a matching function based on choice between different portion-sizes of food produced by responding on identical VI schedules. Each data point is an average of six dogs' performance over several days. The details of the experiment, and a discussion of deviations from matching which were found in the individual-dog's data, are provided in the actual paper. The plot is simply illustrative here.

Note, first, that the logs of the two ratios are plotted. This is a common practice that offers analytical advantages discussed elsewhere [1]. Second, each point on the graph shows the relationship between the (logged) ratios obtained when choice was between a single pair of food portion-sizes. The two points in the center of the graph come from separate replications of a condition in which the two schedules provided equal portion-sizes. The three points to the upper right are from three pairs of different portion-sizes: the lower three points are from the same unequal portion-sizes when assigned to the two levers in a counterbalanced fashion (i.e., if portions A and B were originally assigned to the left- and right-hand levers, respectively, they were subsequently assigned to the right- and left-hand levers, respectively). The actual ratios plotted here were obtained by computing the right-lever/left-lever ratio, whatever the schedules assigned to those levers). Third, a line of best fit drawn through the points can then be used to estimate the relation obtained. A line with a slope of 1.0 would reflect a perfect matching of behavior-ratios to food-ratios. The slope of the line in Fig. 1 is 1.02, very near to perfect matching. The value of the \( Y \) intercept of the line indicates the degree of side-bias in responding to one lever. In the figure, the intercept value is +0.05, reflecting essentially no side-bias. In some applications of concurrent schedules to hedonic scaling, the value of the \( Y \)-intercept is the most important factor in deriving a scale-value for the food-item which produces the bias (see below, also [5,23]).

APPLICATION OF THE CONCURRENT-SCHEDULES PROCEDURE TO THE STUDY OF FOOD PREFERENCES

The concurrent schedules methodology has been used most often to compare animals' reactions to schedules that provide food in quantitatively specified ways [10]. For example, in the hypothetical case discussed above, the two operant schedules provided a given portion-size of food at different rates. In the case of the data shown in Fig. 1, the schedules provided food at the same rate but the portion-sizes varied in weight (see [10] for a review of the literature). Concurrent schedules have also been used to compare animal's reactions to food-items that differ in a qualitative way [15, 19, 22, 23], and it is this application that is of most interest in testing the food preferences of dogs. This line of work is based on an idea of matching that is more general than we have discussed above. It is that the ratio of responses made on the two schedules reflects the ratio of the values of the feeding opportunities provided by the schedules [1, 18, 20, 26]. In this framework, "value" is meant to encompass quantitative and qualitative differences between the schedules and/or the foods being tested. According to this logic, the concurrent-schedules procedure could be used to quantify the hedonic value of foods which differ in ways that are not easily quantified, such as in flavor or in texture.

In general, the strategy followed in using the concurrent-schedules procedure to scale the hedonic value of foods that differ in flavor, say, is (1) generate a standard 'matching' function, such as that shown in Fig. 1, using schedule-alternatives that differ jointly in some quantitative dimension (e.g., rate at which food is made available on two VI schedules) and in the flavor of the foods they provide. (2) Use the value of the \( Y \)-intercept of the function as an estimate of the ability of one of the flavored foods to introduce a bias in responding towards its lever. (3) once the relative value of the original two flavors (A and B, say) is estimated in this way, compare a new flavor, C, against one of those originally tested (e.g., Flavor C vs. Flavor B) by constructing a second matching function. (4) By assigning an arbitrary value to one of the flavors (B, say) a matching-based hedonic scale could be constructed showing the positions of the other flavors tested relative to B. (5) finally, the scale could be validated by directly comparing Flavor A against Flavor C.

The best example of this application of concurrent schedules is Harold Miller's [23] successful scaling of the hedonic value of different seeds for pigeons. An experiment by Chao [5] later in this monograph applies this strategy to the scaling of dogs' hedonic reactions to sugars.

TRADITIONAL TWO-BOWL TESTS AND CONCURRENT OPERANT SCHEDULES: WHICH TO USE?

In comparison to the traditional two-bowl preference test, the concurrent-schedules methodology is technically demanding and time consuming. By its very nature, the method involves the study of preferences in a few highly trained animals with which tests must be conducted for relatively long periods of time in order to obtain the kind of data necessary for constructing a scale of hedonic value. Nevertheless,
the concurrent-schedules method offers some important potential advantages over the two-bowl test.

For one thing, it seems capable of providing rather good measurements of hedonic value that can form the basis for a quantitative hedonic scale.

Second, it seems likely to assess an animal's reactivity to food with minimum complications from post-ingestional influences of feeding because relatively little food is consumed in the test. However, it must be recognized that even limited stimulation by sensory aspects of the food (e.g., taste, texture, smell) could trigger important physiological adjustments (e.g., insulin release) associated with ingestion in experienced animals [4,25]. (It is worth noting, that the two-bowl test can also be conducted in a way that limits post-ingestional effects on preferences. For example the test used by Ferrell [11,12], in which a pair of bowls was rotated into the test-chamber several times during a testing session, presented very limited amounts of food and tested the animal's choice repeatedly.)

Third, there is only a limited amount of food available to be tested (as when a new food is being developed by a manufacturer, say), a relatively small amount of food can generate a sizable amount of preference data in the concurrent schedules test.

Finally, because the "currency" in which the foods' relative value is measured is the lever-press, it is possible to use this common currency to compare foods that differ in significant, but not easily quantified, ways. Consider, for example, a test between foods that differ in texture, moisture, and so on, such as a kibbled dry food vs. a semi-moist (burger type) food. Suppose that in a two-bowl test a group of dogs ingested 200 g of both foods, on the average. The interpretation of this result is complicated by certain considerations. For example, it is likely that the dogs would use different chewing patterns in "handling" the two foods, and it is not always clear how (or whether) to take this factor into account. The concurrent-schedules methodology seems worth applying to problems such as this since it minimizes consummatory behavior and makes estimates of preference on the basis of a common currency, the operant response.

There has been interest in examining the way operant assessments of the value of food relate to the more traditional consummatory-response methodology and, unfortunately, that relationship is not simple (e.g., [8, 9, 15, 16, 29]). However, it must be emphasized that even consummatory-response tests, when conducted under different circumstances (e.g., lasting for different durations), can themselves produce discrepant outcomes (e.g., [6, 27, 32, 33]). Upon reflection, this state of affairs is about what one would expect. That is, the various test-methodologies, and even the various conditions under which a given methodology is applied (e.g., short- vs. long-term test), can be viewed as different measuring instruments for evaluating an animal's reactions to foods. Depending on what the instrument measures, and the level of measurement it provides, measurements of a given food's value obtained with the different instruments may agree only in part, or even not at all. The problem is to understand the measuring instrument and its function as well as possible in order to make an informed interpretation of the measurements it provides. Of course, this requires a considerable body of basic research relating the various measuring instruments themselves. There has been no co-ordinated and sustained effort on this problem as yet. Under the circumstances, the best advice about which test to use is: with knowledge of the fine-points of the various tests in mind, match the test to the problem being studied on the basis of what the test is known to measure and the logic of interpreting the data it returns.

THE CONCURRENT-SCHEDULES PROCEDURE IN THE STUDY OF DOGS' FOOD PREFERENCES

Kitchell [21] has applied an elementary version of the concurrent schedules methodology to the study of food preferences in dogs. The next three papers in this monograph summarize our main attempts to apply a version of this method to the study of dogs' food preferences. Our application is more complex than Kitchell's and is closer to the laboratory procedures developed in operant conditioning.

The first paper, by Green and Rashotte [13], constitutes a study of the way dogs react to quantitative differences in food-items, and it serves as a kind of "calibration" experiment for the concurrent-schedules procedure with a new species. In one experiment, the operant schedules associated with the two levers made food available at an identical rate (VI 60-sec schedules), but the size of the food-items presented was varied (by weight) across the two schedules. The results are in general agreement with those obtained under similar conditions with other species: the individual-animal results show orderly functions that deviate somewhat from "matching." In a second experiment in this paper, the dog's switching behavior from one lever to the other was found to be influenced in an orderly way by the length of the changeover delay.

The second paper, by Chao [5], reports the outcome of an experiment close in design to that employed by Miller to scale the hedonic values of different seeds for pigeons. Chao's experiment applies the concurrent schedules methodology in scaling the dog's hedonic reaction to sucrose and glucose presented in solution.

The third paper, by Rashotte, Foster and Austin [28], employs a very limited version of the concurrent-schedules procedure to compare the value of food items that differ in some dimension(s) of flavor and/or texture. This paper includes a direct comparison between lever-press and two-bowl tests.

Taken together, these experiments indicate that the concurrent-schedules procedure can be a useful testing method for quantifying some aspects of dogs' preferences for different foods, and that it could help provide the basis for a matching-based hedonic scale of canine food preferences.

REFERENCES


