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Assessing Animals' Preferences: Concurrent Schedules of Reinforcement

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Three methods of assessing animals' preferences are outlined: free-access, two-choice (e.g., T maze), and concurrent-schedules. While all give indications of relative preference between the choices, free-access and discrete-trial procedures tend to give exclusive preference and so do not indicate the degree of preference. Concurrent schedules give at least ordinal measures of the degree of preference. Data from cows, hens, and brushtail possums are used to illustrate the use of concurrent schedules to assess food preferences. The use of multiple-concurrent schedules to assess preference between sounds, and of concurrent-chain schedules to assess preference between waiting with or without another hen present are illustrated by studies with hens. Concurrent schedules, while not replacing other methods, are useful in evaluating preferences.

One concern in deciding what should be provided for captive or domestic animals is the animals' likes and dislikes. Therefore, as Dawkins (1977, 1990) pointed out, data relating to animals' preferences are important in the assessment of animal welfare. At the Animal Behavior and Welfare Research Centre (ABWRC), Hamilton, New Zealand, we have been concerned with developing (and assessing the utility of) different methods of assessing animals' preferences for a wide range of environmental stimuli.

Most preference assessment procedures involve offering the animal a choice, in some way, between two or more events or environments. One aspect of all preference measures is, as Duncan (1978) pointed out, that they provide relative, as opposed to absolute, information about the value of the choice alternatives. In addition, the results of a preference test might allow us to conclude that an animal prefers Environment A over Environment B, but the animal may like or dislike both environments. That is, we could not conclude that the animal actually likes Environment A, nor could we conclude that the animal dislikes, or will suffer in, Environment B. Another issue in interpreting the results of all preference tests is, as both Duncan (1981) and van Rooijen (1982) pointed out, that animals will not always choose in the interests of their long-term welfare. Just as an adult human may choose to smoke cigarettes, an animal may choose to eat a particular food that makes them sick or poisons them. In interpreting an animal's choice, we also need to take into account any delay in accessing the consequences as delays to the consequences can influence which consequence is chosen (Ainslie, 1974; Rachlin & Green, 1972). Depending on the relative delay, a small immediate consequence may be preferred to a larger more delayed one. That is, an animal may choose an immediate consequence that is not good for them in the long run. It may, for example, choose to eat too much and so become obese. All measures of preference, however obtained, have to be interpreted in the light of these considerations. Three

main approaches have been used to assess animal preferences. In the simplest choice method, the animal is allowed free access to two or more simultaneously available environments or events, and the time spent in or interacting with each (the dwell time) is measured. This method has been used extensively in assessments of animals' preferences for a wide range of environmental features, such as cage flooring type (Hughes & Black, 1973, using hens; Ponteaux, Christison, & Stricklin, 1983, using pigs), cage size (Dawkins, 1977, using hens; Blom, et al., 1995, using laboratory rats), and food type (Matthews, 1983, using cows).

Free-access procedures are relatively easy to implement in both laboratory and naturalistic settings. They require a simple response from the animal and provide a rapid means of collecting preference data. However, using the proportion of time allocated to an environment or event as a measure of preference can present some problems in interpretation, as the time spent in an alternative does not necessarily indicate the value of an alternative. If the environments the animal has to choose between are unequal in size, random wandering may bias the preference measure towards the larger environment (Dawkins, 1977). In addition, as Duncan (1978, 1987) pointed out, an animal may choose to spend only 5% of its time in one environment, but that environment may be equally as important as the 95% choice. For example, although laying an egg is not an activity that takes up much of a hen's time, access to an environment (e.g., nest site) in which to lay may be very important for them and for their welfare. A further consideration in using free-access procedures is that, as several researchers (e.g., Hughes, 1976; van Rooijen, 1982) have reported, free-access preference measures may differ depending on whether the animals were free to come and go from the choice environments, or were forced to wait for a period after entry. It may also not be practically possible to provide free access from one environment to another when preferences between some environmental conditions (e.g., lighting, temperature) are being measured (Temple & Foster, 1980).

Another choice method, the T-maze procedure, requires the animal to make a simple response (e.g., turning left or right in a T maze) before entering one of two environments for a period (e.g., Lindberg & Nicol, 1996, with hens, and Patterson-Kane, 2002, with rats). Preference for one environment over another is inferred on the basis of the arm of the T maze chosen and/or the latency-to-choice measure (the speed at which the animal moves from the start arm of the T maze to one of the choice arms). In some studies, each animal is given one choice and the measure of preference is the percentage of animals choosing an alternative. This means that if 80% of the animals select one option the preference is said to be for that option. It is not clear how to interpret this result given that 20% of the animals selected the other alternative. In other studies, each animal is given many choices and the proportion of times an animal selects one option is taken as its measure of preference. This later method has the advantage of giving individual preference measures and allowing assessment of individual variation across animals.

A problem with choice procedures such as the free-access and the T-maze procedures is that, if there is any meaningful difference between the choice alternatives, the animals are likely to choose the same option on nearly every trial. This problem can be illustrated by the results of Matthew's (1983) examination of dairy cows' (*Bos taurus*) food preferences using a free-access procedure. He took two free-access measures; the food first eaten and the relative amounts consumed.

When one of the two foods presented was highly preferred to the other (determined using another preference procedure) the cows consumed all of the 'preferred' food and none of the alternative food on 34 of 35 occasions. These exclusive choices gave relative intake measures of 1.00. However, both when there was a small preference for one food relative the other, and when there was no preference (determined by another preference procedure), the cows generally (on 80 of 91 occasions) consumed all of one food and then all of the other food. Which food was eaten first depended on the side of the chamber the food was presented on that session. This gave relative intake measures of 0.50, suggesting indifference. The relative intake measures in this study were, then, either 1.00 or 0.50 and so provided no information on how much one food was preferred over another. That is, they did not yield graded (or quantitative) measures of preference. Similar results have been obtained with T-maze procedures.

The third method of assessing preference also allows animals a choice and is known as the concurrent-schedule procedure. This procedure requires the animal to make an arbitrary response, such as a key peck or lever press, to obtain reinforcement. It involves presenting the animal with two or more simultaneously available but incompatible response manipulanda (e.g., keys that can be pecked or levers that can be pushed). Responses on these result in intermittent access to either of two consequences (reinforcers), such as two different foods. The schedules that determine how often each consequence is available, known as the schedules of reinforcement, are generally time based. Typically, variable-interval (VI) schedules are used wherein the reinforcer becomes available for responses made after pre-selected but variable periods of time have elapsed since previous reinforcer delivery. VI schedules are used because, under this scheduling, animals will sample both alternatives and, in doing so, they can increase their reinforcement rate. Although concurrent schedules have been used to study the effects of delays to reinforcement (Chung & Herrnstein, 1967; Rachlin & Green, 1972), under VI schedules the consequences are normally available immediately after the designated response.

Sometimes the VI schedules leading to each alternative are arranged independently so that the availability of the reinforcer on one schedule in no way affects the availability of the reinforcer on the other schedule (Herrnstein, 1961). This does allow extreme preferences to result in the exclusive choice of one alternative. To reduce the possibility of exclusive choice and to keep the relative reinforcement rates obtained under the schedules as programmed by the experimenter, most preference studies use dependent scheduling. Under dependent scheduling, when a reinforcer is due on one alternative, the schedule associated with the other alternative stops timing until that reinforcer is collected (Stubbs & Pliskoff, 1969). This helps ensure that both alternatives are sampled at least occasionally and can prevent exclusive preferences developing. Stubbs and Pliskoff (1969) showed that dependent and independent scheduling produce similar results when reinforcement rates are varied. Whichever method is employed, the ratios of the number of responses made and the ratios of the amount of time spent responding on each alternative are taken as measures of the animals' preferences.

With dependent scheduling, it is possible that with extreme preferences between reinforcers, behaviour could be maintained by the dependency alone. To examine this possibility, Matthews and Temple (1979) used concurrent dependent

schedules with cows and an empty hopper as the consequence on one of the schedules. The other schedule delivered access to chopped hay. Four cows ceased responding on either schedule and two cows continued to respond somewhat to both alternatives. Matthews and Temple (1979) conclude the dependent contingency may therefore have maintained some small amount of responding and that the observed preferences may have been smaller than the “true” preferences. They argued that they would still suggest the use of the dependency because it has little effect at most preference values except to equalize the obtained rates of reinforcement.

The concurrent-schedule procedure has been shown to provide a measure of the degree of an animal’s preference for one environmental feature over another (i.e., it allows quantification of choice). Davison and McCarthy (1988) provided a review to that date of the procedure and its use. As Davison and McCarthy (1988) point out, concurrent-schedule performance is usually quantified using the Generalized Matching Law (GML; Baum, 1979). Expressed mathematically, this is:

$$\log\left(\frac{B_1}{B_2}\right) = a \log\left(\frac{r_1}{r_2}\right) + \log c \quad (1)$$

where B refers to the number of responses or time spent responding, r refers to the number of reinforcers obtained, and the subscripts denote two alternatives. The parameter a , termed sensitivity to reinforcement (Baum, 1979), measures how much the behavior ratio changes with variations in the reinforcement-rate ratio. The parameter c , termed bias (Baum, 1974), measures the magnitude of the preference for one alternative relative to another, over and above reinforcement-rate differences. By way of example, if the reinforcement rates were equal (i.e., $\log(r_1/r_2) = \log(1.00) = 0$), if c were 2 ($\log c = 0.30$) and the behavior ratio was taken to the left alternative, then twice the number of responses were made (or twice the amount of time was spent) on the left alternative. This result implies that the left alternative was preferred twice as much as the right.

It should be noted that the previously outlined limitations regarding preference measures, including the fact that they are all relative, also apply to concurrent schedules. It should also be noted that, like all preference measures, concurrent schedules provide information on an animal’s preferences between the offered options only. Frequently, for example, it is the time of access to food that is controlled rather than amount of feed provided for each reinforcer. Hence, if an animal is choosing between 3-s access to one food and 5-s access to another food the resulting preference measure is influenced by all the differences between the options, such as food quality and amount eaten, and not just the amount or quality alone. To separate out the effects of food quality would require control over the amounts. Thus, although a study examining animals’ choices between 3-s access to crushed barley and 3-s access to dairy meal might report that ‘the animals preferred crushed barley to dairy meal’, what should be taken from this is that the animals preferred 3-s access to crushed barley to 3-s access to dairy meal. In another example, if a hen was given the choice between 5-s access to peat and 5-min access to sawdust for dust bathing, then the resulting preferences would necessarily apply to these times of access to the materials only, and would not necessarily apply to the materials alone. The same caution applies to the interpretation of any

preference measures obtained where the access to the options is limited in some way.

A large number of studies have examined animals' preferences using concurrent schedules, the GML and a range of independent variables (e.g., reinforcement rate, Lobb & Davison, 1975; reinforcer quality, Hollard & Davison, 1971; Matthews & Temple, 1979; Miller, 1976; delay to reinforcement, Chung & Herrnstein, 1967; response type, Davison & Ferguson, 1978; McSweeney, 1978; Sumpter, Foster & Temple, 1995). The resulting preference measures have been found both to be sensitive to very small changes in the independent variables (McCarthy & Davison, 1988), and to provide information on the value that such variables, in combination, have for an animal (Baum & Rachlin, 1969; Killeen, 1972). Because they provide information about the size of an animal's preference for one alternative over another, a rank order or scale of an animal's preference for a variety of environmental features can also be obtained. Although many of these studies have used pigeons as subjects and food as the consequences, some have examined the utility of the concurrent-schedule procedure for assessing the preferences of a wider range of species for a range of different consequences. In doing this, new equipment has had to be developed, and the traditional concurrent-schedule procedure has sometimes been modified.

Concurrent-Schedule Research at the ABWRC

To illustrate some of the ways the procedure has been used, this paper presents examples from the research carried out at the Animal Behaviour and Welfare Research Centre (ABWRC, Waikato, NZ) over a number of years. The initial impetus for this research came from Ron Kilgour (see Kilgour et al., 1991). Kilgour et al. (1991) reviewed the use of operant techniques as a means of providing data to help with managing farm animals. They included a section on operant research to that date at the ABWRC. This covered the use of concurrent schedules to assess and quantify animals' preferences for various environmental features. Further research has been completed since that time and the remainder of this paper will cover both the early research and more recent research on preference measurement conducted by research students and staff at the ABWRC. The ABWRC laboratory has continued to undertake both basic research in the area, and research into the ways of adapting procedures so that they provide data of applied relevance.

Assessment of Food Preferences

In an early study, Matthews and Temple (1979) examined dairy cows' food preferences by presenting the cows with a choice between 3-s access to chopped hay and 3-s access to dairy meal (a concentrated feed) on dependent concurrent VI VI schedules. A plate press, made by the cow's muzzle, was the required response and the food was delivered in hoppers that could be reached by the cow once raised. Figure 1 shows an aerial view of the experimental equipment used and a cow pressing the right response plate. To prevent the adventitious reinforcement of switching between alternatives, which may occur under time-based schedules, a 2-s changeover delay (COD) was included in the procedure. A COD specifies the minimum amount of time (usually 1 to 3 s depending on the species)

that must elapse between the first response on an alternative and a reinforcer for a subsequent response on that alternative following a changeover (Herrnstein, 1961). In the first experimental condition, the two food hoppers, one associated with each response plate, contained chopped hay and the rate of reinforcement delivery was the same (VI 60 s) on both alternatives. This condition was conducted to measure the bias towards one alternative due to position preferences or other factors not associated with different foods (termed inherent bias; Baum, 1974) for each cow. The reinforcement rates associated with presses on the left (hay) and right (dairy meal) plates were then varied to assess whether the difference between the feeds made a constant contribution to the relative value of the alternatives over the different reinforcement-rate ratios. To gain a measure of bias due solely to the different feeds, the individual inherent biases obtained during the first condition were subtracted from the biases obtained from the latter conditions. Matthews and Temple (1979) analyzed their results using a modified version of the generalized matching law (GML) in which preference between qualitatively different reinforcers is viewed as a special case of response bias:

$$\log\left(\frac{B_1}{B_2}\right) = a \log\left(\frac{r_1}{r_2}\right) + \log q + \log b \quad (2)$$

where $\log b$ is a measure of inherent bias, $\log q$ is a measure of bias due to the different feeds (the food preference) (note that $(\log b + \log q) = \log c$ (Equation 1)), and the remaining parameters are as previously defined. Matthews and Temple found that preferences, as measured by $\log q$, were roughly constant over the range of reinforcement rates studied. They reported that some cows showed small preferences for hay while others showed small preferences for dairy meal, and that the response and time measures did not always agree. They suggested that the different times taken 'handling' each food (such as the amount of chewing required) after removing it from the magazine might have been a factor in their results.

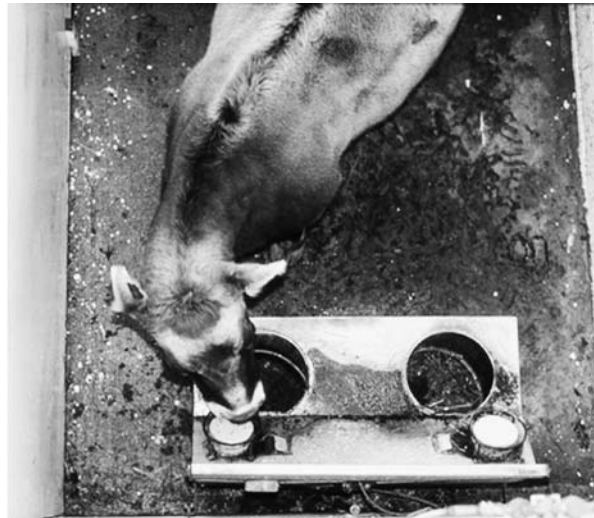


Figure 1. An aerial view of a cow in the apparatus used to study food preferences using a co current-schedule procedure.

In a later study, Matthews (1983) investigated whether concurrent-schedule data, analyzed using Equation 2, could be used to predict and scale dairy cows' preferences for different feeds. Six maize silages were each paired with crushed barley on equal dependent VI schedules of reinforcement. The resulting food biases ($\log q$) from both response and time measures were then used to rank order preference for the silages relative to crushed barley. Figure 2 presents the scales derived from the response and time measures for the group data. Based on an assessment of the degree of transitivity of the preference measures obtained (see Sumpter, Temple, & Foster, 1999, for a detailed description of the various forms of transitivity and their implications), Matthews (1983) reported that the scales derived from the response bias measures could be used to predict both the magnitude and direction of the preferences observed when previously unpaired feeds were later paired in the concurrent-schedule procedure. By contrast, only the direction of those preferences could be accurately predicted from the scales derived from the time bias measures. He again suggested the difference in response and time measures might be accounted for by the different feed handling times.

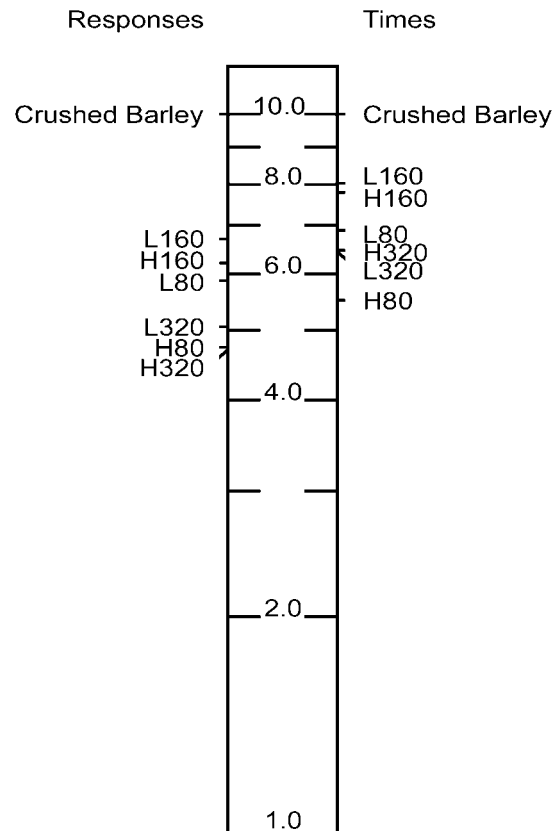


Figure 2. Scales of the preference values of six silages (coded) and crushed barley (CB) derived from the group response and time bias measures obtained in Matthews' (1983) study. Crushed barley served as the standard food in all comparisons and was assigned a value of 10 units. The scales are logarithmic.

Foster et al. (1995) have since shown that food quality worked as a constant biaser for cows responding under concurrent schedules, even when the preference between the feeds were much more extreme than found in the earlier research. They also showed that the time spent chewing the food after it had been taken from the magazine did contribute to the difference between the response and time data.

Matthews (1983) argued that food preference scales might be useful on a number of counts. The utility of new dietary items for animals could be assessed by comparing their preference values with those of other items on the scales. Insight into the ways in which palatable ingredients could be added to unpalatable feeds to produce an acceptable mixture could also be gained by examining the relative preference values of different feeds. Since Matthew's (1983) study, other studies at the ABWRC have used the concurrent-schedule procedure to rank order and scale cows' preferences for a wider range of foods (in all cases the preference was measured relative to crushed barley), and the resulting scale (based on average response bias measures) from this work is presented in Figure 3.

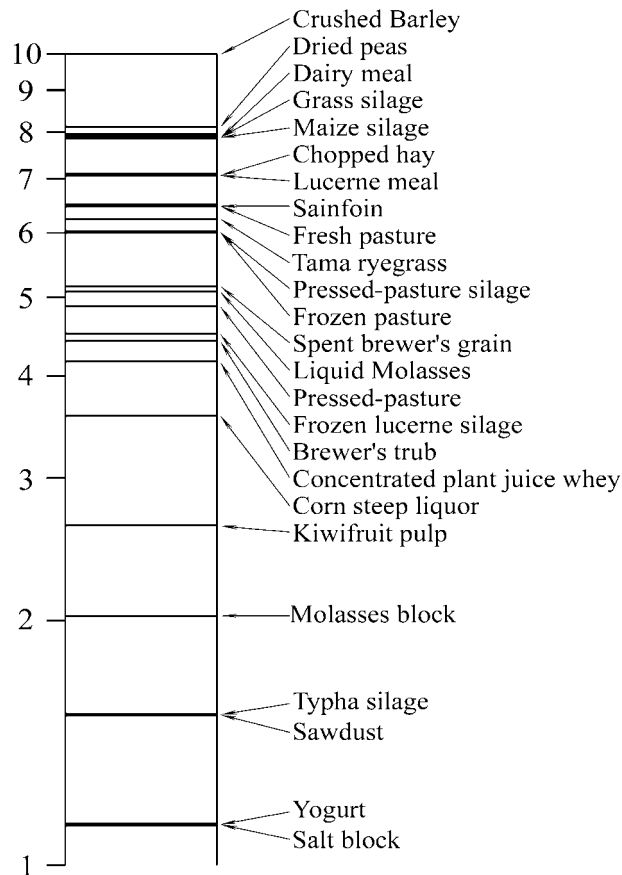


Figure 3. A logarithmic scale of cows' food preferences for a range of foods, based on the average response bias measures, obtained using a concurrent-schedule procedure. Crushed barley served as the standard food in all comparisons and was assigned a value of 10 units.

In a recent study (Flevill, 2002), concurrent schedules have been successfully used to measure the food preferences of domestic hens (*Gallus gallus domesticus*). Flevill used a procedure similar to that used by Matthews (1983) (but with equal VI schedules only) to examine hens' preferences between three wheat-based foods. The hens pecked at lighted keys (as shown in Figure 4) and the inherent bias measures were obtained from a condition in which the standard food (wheat) was presented in each of the two food magazines. In two other conditions, puffed wheat and honey-puffed wheat were each paired with the standard food to assess the hens' preference for those foods relative to wheat. As seen in Table 1, Flevill's results indicated that, for the group response- and time-based measures, the hens preferred wheat most, followed by honey-puffed wheat and then puffed wheat.



Figure 4. A hen in an experimental chamber key pecking under a schedule of food delivery.

Bron et al. (in press) have shown that a marsupial, the brushtail possum (*Trichosurus vulpecula*), responds similarly to other animals on concurrent schedules. She has also shown that the procedure could be used to assess their preferences between different pairs of feeds, using a bar press response, and that she could vary the degree of bias by adding different amounts of salt to a food. The possums in Bron et al.'s study had response panels attached to the front of their home cages and the levers were removed between sessions. Figure 5 shows a possum in its experimental cage pressing a lever.

Table 1.
Logarithmic Response and Time Bias Ratios Obtained from Flevill's (2002) Study.

Hen	Response			Time		
	W vs W	W vs PW	W vs HPW	W vs W	W vs PW	W vs HPW
61	-0.14	0.52	0.48	-0.05	0.61	0.47
62	-0.21	0.91	0.56	-0.05	0.95	0.42
63	-0.21	0.41	0.41	-0.23	0.26	0.43
64	-0.11	0.77	0.35	-0.23	0.79	0.42
65	-0.03	0.34	0.22	-0.02	0.13	0.29
66	-0.19	0.71	0.69	-0.01	0.68	0.64
μ	-0.15	0.61	0.45	-0.10	0.57	0.45

Note. presented are the logarithms of the response- and time-allocation bias ratios obtained during the wheat versus wheat (W vs. W), wheat versus puffed wheat (W vs. PW), and wheat versus honey-puffed wheat (W vs. HPW) conditions of Flevill's (2002) examination of the food preferences of hens. A positive bias estimate indicates a bias towards the left (W) alternative. The larger the positive bias estimate, the greater the bias towards wheat.



Figure 5. A possum in its home cage with the response panel attached and the response levers inserted, lever pressing under a schedule of food delivery.

Martin (2002) compared the food preferences of brushtail possums using three different choice procedures. She used a similar apparatus to that shown in Figure 5 but with two food magazines in all procedures. The food magazines could be raised to allow access to the foods for specified time periods. Two of the procedures required lever presses. The procedures were; concurrent schedules (using the same method as Flevill, 2002) with two levers and 3-s access to the food magazines, a free-access procedure (in which both magazines were raised most of the time, but both had to be lowered and immediately raised again every 3 s to move the food down the hopper and in which no lever press was required), and a procedure in which both food magazines were raised together (and remained raised for 3 s) after every central lever press (the one-lever procedure). Martin (2002) gave her 6 possums the choice between rolled oats (RO) and a barley/sunflower seed mixture (BSF) and between RO and a breakfast cereal (San Bran, SB) with all three procedures. Figure 6 presents the data from one possum (Astra) for all three procedures to illustrate the findings. For the RO versus SBF choice, the concurrent-schedule data indicated preferences close to indifference (around 0.50) between RO and BSF (top row, left panel), the one-lever procedure (top row, middle panel) resulted in relative times-spent measures close to 0.00 (i.e., exclusive preference for BSF), and the free-access procedure (top row, right panel) gave relative-time spent eating measures of 1.00 in some sessions and 0.00 in others. Whereas, for the RO versus SB choice, the concurrent-schedule data indicated a strong preference for RO (values > 0.50 ; bottom row, left panel), the one-lever procedure (bottom row, middle panel) resulted in relative time-spent values in the same direction as the concurrent-schedule data (generally > 0.50), while the free-access preference measures (bottom row, right panel) gave relative-time spent eating measures of 1.00 (exclusive preference for RO) every session. Astra's data are typical of the other possums' data in that, when the concurrent-schedule data indicated indifference or moderate preference, the free-access data were variable, tending to either 0.00 or 1.00 or swinging between these. Astra's data differ from those of some of the other possums in that, in these cases, the one-lever data sometimes also indicated moderate preference or indifference. Astra's data were similar to the other possums' data in that a strong preference in the concurrent-schedule data was accompanied by preference in the same direction from the one-lever procedure and exclusive preference (also in the same direction) from the free-access procedure.

Martin's (2002) free-access data are similar to those found with cows by Matthews (1983; mentioned previously), although Martin found more exclusive free-access preferences when the concurrent-schedule data indicated moderate preferences, than did Matthews. One difference between the procedures was that Matthews's cows were able to eat all of both of the foods in a session while Martin's possums could not empty even one of the magazines in the available time. The relative amounts eaten and times spent eating for a cow sometimes resulted in indifference (0.50) simply because the cow had eaten all of both foods. Martin's data suggest that when there was a moderate preference between the foods (as indicated by the concurrent-schedule data), although the possums could switch to the other magazine, they tended to stay eating from the one they started with in that session under both the free-access and one-lever procedures. The possums were more likely to eat from both magazines at some point in a session when a single

central response was required to re-operate the magazines (the one lever procedure). One way to research this aspect of these two procedures further would be to alternate the side the food was on from session to session. Martin (2002) kept each food on the same side, as her aim was to compare data from these procedures with those from a concurrent-schedule procedure in which the food is normally on the same side each session. On the basis of her results, Martin (2002) concluded that the concurrent-schedule procedure was a good method to use to get a measure of the degree of preference between two foods but that it was expensive in terms of both time and equipment. She suggested that the one-lever procedure requiring the central response was the next best procedure to use to get interpretable preference measures as, although this procedure resulted in exclusive preference measures, it did so less often than the free-access procedure.

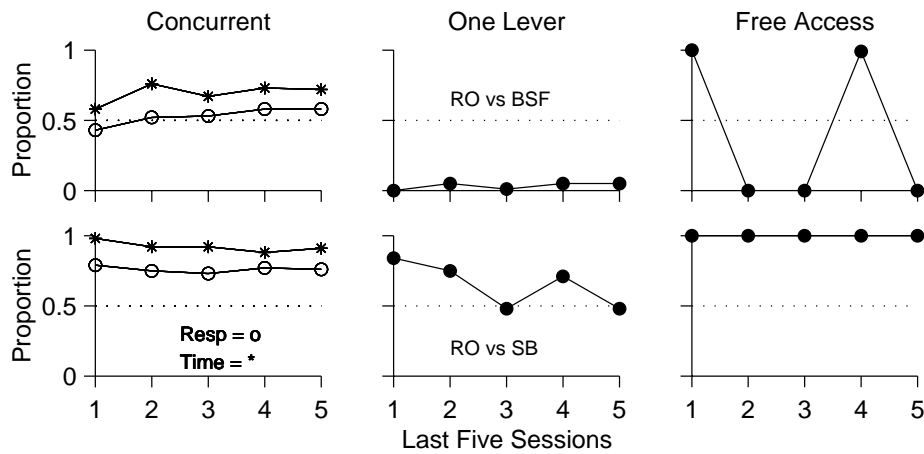


Figure 6. The preference measures obtained from the last five days of the concurrent-schedule (left panel), one-lever (middle panel), and free-access (right panel) conditions of Martin’s (2002) study for one possum (Astra) responding for rolled oats versus San Bran (top row) and rolled oats versus a barley and sunflower seed mixture (bottom row).

Assessment of Preference for Other Stimuli

While concurrent schedules have proved useful in assessing preferences for environmental events that an animal will respond to obtain, they cannot be used in the same way for preference assessments involving stimuli that will not maintain an animals’ responding (e.g., potentially aversive stimuli). Whether or not a stimulus such as electric shock is aversive, has been assessed by whether or not an animal will learn to escape or avoid it or to turn it off. We were interested in whether hens found loud sounds aversive. In an early study on this, Muller (1987) found that hens would not learn to turn off loud (up to 120 dB) pure tones at frequencies within their hearing range using a procedure similar to those that had been found to work with electric shock. Following this, Mackenzie, Foster, and Temple (1993) arranged an experimental chamber so that when a hen stood at one end a sound was relayed centrally into the chamber, and when the hen moved to the other end of the chamber the sound would turn off. Moving back would turn the sound on again. Over a series of conditions they found that pure tones at a range of decibel

levels (from 60 to 100 dB) did not cause the hens to move to turn the sound off. The hens tended to stay in a particular end of the chamber regardless of whether that turned the sound on or off, or they would move randomly around in the chamber. Mackenzie et al. (1993) then tried using some more natural sounds recorded on short loops of tape. The sounds included a dog barking, a train, a piece of music, a high-pressure water hose, and hens in a commercial poultry shed during feeding time. These sounds, when played at 90 dB, did result in the hens spending proportionally more time with the sound off than on. The recording of the sound of hens in a commercial poultry shed at feeding time at 90 dB resulted in most hens spending more time with the sound turned off than for any of the other sounds. Mackenzie et al. (1993) also used this sound at 80 and 70 dB and found, interestingly, that the higher the decibel level the more time the hens spent with the sound turned off. This was surprising given that the hens simply had to stand at one end of the chamber to keep the sound off. The results of this study suggested such hens might find some of these sounds aversive.

In order to study this further, McAdie et al. (1993) used a procedure under which some of the same sounds used by Mackenzie et al. (1993) were overlaid on one of two independent concurrent VI 90-s VI 90-s schedules of food delivery. In the first 10 min of a session, the two key lights were lit red and there was a VI schedule associated with each key. A response on the left key turned on the sound, which continued to be played until a response was made on the right (no-sound) key. In the second 10 min of a session, the key lights were lit green and the conditions were reversed so that the sound was played when the hen responded on the right key. This sequence was then repeated so each session lasted 40 min. This scheduling arrangement is termed a multiple-concurrent schedule, and allowed McAdie et al. (1993) to assess the biases resulting from the presence of a particular sound within a single experimental condition. Although the VI schedules were independently arranged so that the hens were not forced to respond in the presence of a loud sound, the use of VI schedules of food delivery meant that that the hens would respond on both alternatives.

McAdie et al. (1993) found that for most of the sounds the hens responded less, and spent less time responding, on the key associated with the sound (when at 90 dB). Moreover, they found that the magnitude of the resulting biases increased as the intensity of the sounds increased (from 90 dB to 95 dB and then 100 dB). On the basis of these results, McAdie et al. (1993) argued that no sound was preferable to most of the sounds used, that these sounds might have been aversive to the hens, and that their potential aversiveness increased with intensity. Interestingly, the largest biases were away from the key associated with the loop of tape of the sound of hens in a commercial poultry shed during feeding time. In a later study, McAdie, Foster, and Temple (1996) also showed that the biases resulting from a particular sound remained relatively constant when the rates of food delivery were varied, supporting the GML analysis of these data.

In both of the abovementioned studies, large biases resulted from the sounds when only responses that occurred 2 s after each changeover (i.e., post-COD data) were considered, whereas there were little or no biases during the 2-s COD. This result is a similar finding to the commonly found insensitivity of concurrent-schedule behaviour during a COD to reinforcement parameters (e.g., Temple, Scown, & Foster, 1995). It also indicated that the hens did not stop respond-

ing on sound onset, and that the sounds did not appear to elicit behaviours incompatible with key-pecking, as they continued to peck throughout the COD. In a more recent series of studies, McAdie (1998) found that the presentation of white noise also gave rise to large response biases away from the noise when all responding was included in the analysis. Contrary to the results of her previous studies however, the white noise gave rise to only small time biases, and the response biases were greater during the COD than after it (as shown in Table 2). The different changes in the response and time bias measures resulted in decreases in response rate during the white noise presentation without any change in the time allocated to the schedules, and this response suppression was greatest during the COD. McAdie (1998) interpreted this to suggest that the white noise produced behaviour incompatible with responding, as does electric shock (Church, 1971), and on this basis concluded that white noise was actually aversive to the hens. In reviewing her earlier sound data, she suggested that the presence of a sound may have decreased the value of the schedule associated with that sounds, while the white-noise data suggest that the white noise could, as is electric shock, be considered aversive.

Table 2
Noise-Bias Estimates Obtained from McAdie et al.'s (1998) Study.

Hen	Condition	Noise Delivery		Response	Time	Post-COD	During-COD
		Schedule	Length				
61	2/3	-	cont	-0.013	0.039	-0.012	-0.016
	6/7	FR 1	3 s	-0.031	0.104	0.007	-0.120
62	2/3	-	cont	-0.526	-0.189	-0.498	-0.711
	6/7	FR 1	3 s	-0.306	-0.054	-0.286	-0.429
63	2/3	-	cont	-0.045	0.080	0.018	-0.243
	6/7	FR 1	3 s	-0.181	0.048	-0.108	-0.598
64	2/3	-	cont	-0.164	0.025	-0.122	-0.298
	6/7	FR 1	3 s	-0.403	-0.118	-0.342	-0.641
65	2/3	-	cont	-0.156	-0.022	-0.147	-0.174
	6/7	FR 1	3 s	-0.273	-0.034	-0.246	-0.355
66	2/3	-	cont	0.052	0.040	0.108	-0.075
	6/7	FR 1	3 s	-0.116	0.006	-0.063	-0.249

Note. The noise bias estimates obtained from the response, time-allocation, post- and during-COD data from each subject of McAdie's (1998) study are shown. The noise bias estimates were averaged across Conditions 2 and 3 and Conditions 6 and 7 as those pairs of conditions involved the same experimental manipulations. In Conditions 2 and 3, white noise was continuously played when a hen was responding on the left key. In Conditions 6 and 7, white noise was played for 3 s immediately following each response to the left key. A negative sign indicates bias away from the noise, while a positive sign indicates a bias towards the noise.

Assessment of Social Preferences

Walker (1996) wished to study the preferences of hens for other hens (i.e., their social preferences) and decided to use a variant of the concurrent-schedule procedure. A practical difficulty with this comes from the fact that it is not easy to present and remove another hen many times within an experimental session as would be required under either the McAdie et al. (1993) or the Matthews and Temple (1979) procedure. To overcome this problem, Walker (1996) used an experimental chamber similar to that suggested by Temple and Foster (1980). The procedure used was similar to a procedure known as a concurrent-chain procedure. When in the start compartment of the chamber, the hen was presented with two simultaneously available response keys, each key associated with a different VI schedules (termed the initial-link schedules). However, instead of the VI schedules giving access directly to food, each gave access to one of two side compartments into which the hen had to move into and wait (termed the terminal link). After the wait, the hen was given access to the end compartment and to food delivery. After food delivery, the hen returned to the start compartment. The GML can be applied to the data obtained from this procedure to give measures of bias resulting from any differences between the two side chambers. The procedure is useful for studying animals' preferences for stimuli that may not maintain choice behavior in and of themselves. The delivery of food at the end of each cycle ensured that the animal moved through the apparatus and maintained choice responding.

The experimental chamber used by Walker (1996) was an enclosed hexagonal box, as shown in Figure 7, with four compartments connected by motorized sliding doors (D). At the start of each session, the subject hen was placed in the start compartment (A) in which the two response keys (K) were located, one near the left and the other near the right door. Pecks on a key occasionally, according to VI 60-s schedule, opened the door located next to that key. Once the door was opened, it remained open until the hen had moved into the side compartment (as sensed by infrared sensors (S)) associated with that door. Whilst in the side compartment (B), the hen could see (through a spaced wire grid) into a box (C) that was either empty or contained a target hen (a cage neighbor of each subject hen). The subject hen was required to wait in the side compartment (i.e., terminal link) for 60 s before the door into the end compartment (E) opened. Entering the end compartment resulted in 3-s access to food (accessible through a hopper), followed by the opening of the door allowing access back to the start compartment. Once in the start compartment again, all doors were closed, the key lights were once again lit and the hen could make another choice.

Walker (1996) found little preference either for, or against, waiting next to a target hen when she changed which outside box a target hen was in from session to session. However, she obtained consistent measures of preference from each subject hen when a target hen was in the same outside box over a series of sessions (until the preference was stable). The results of those experimental conditions, which are shown in Table 3, showed that all but one of the response and time bias measures were toward the side compartment next to the target hen.

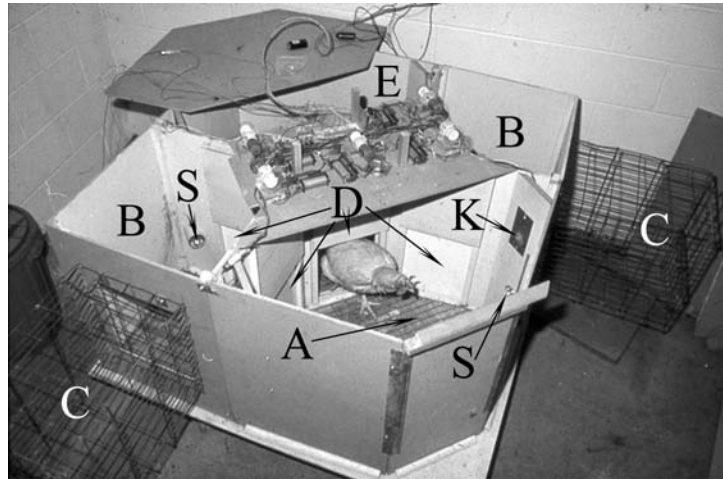


Figure 7. A view of the experimental chamber used in Walker's (1996) and Sycamore's (2001) studies. The hens pictured in the chamber is returning to the start compartment from the end (food) compartment.

Walker (1996) speculated that it could be the social dominance relation between the different pairs of hens that gave rise to these different preferences. Sycamore (2001) used the same procedure to examine whether this was so. She initially observed the hens interacting while housed in an aviary. She counted the numbers of pecks each hen directed at each of the other hens and established the social dominance relations of the hens in the group. Although these were not linear it was possible to pair all but two of the subject hens with both a more dominant and a less dominant hen. As seen in Figure 8, Sycamore found that hens would generally choose to wait next to a hen that was higher than they were in the dominance hierarchy.

Table 3

Logarithmic Response and Time Bias Ratios for all Hens in Walker's (1996) Study on the Social Preferences of Hens.

Hen	Response	Time
61	0.26	0.23
62	0.68	0.53
63	0.13	0.15
64	0.52	0.48
65	0.36	0.42
66	0.28	-0.12

Note. The bias estimates were obtained from the two conditions (Conditions 4 and 5) in which each subject hen was paired with the same target hen. In Condition 4, the target hen was placed on the left, and in Condition 5 the target hen was placed on the right. A positive bias indicates a bias towards the target hen and a negative bias indicates a bias away from the target hen.

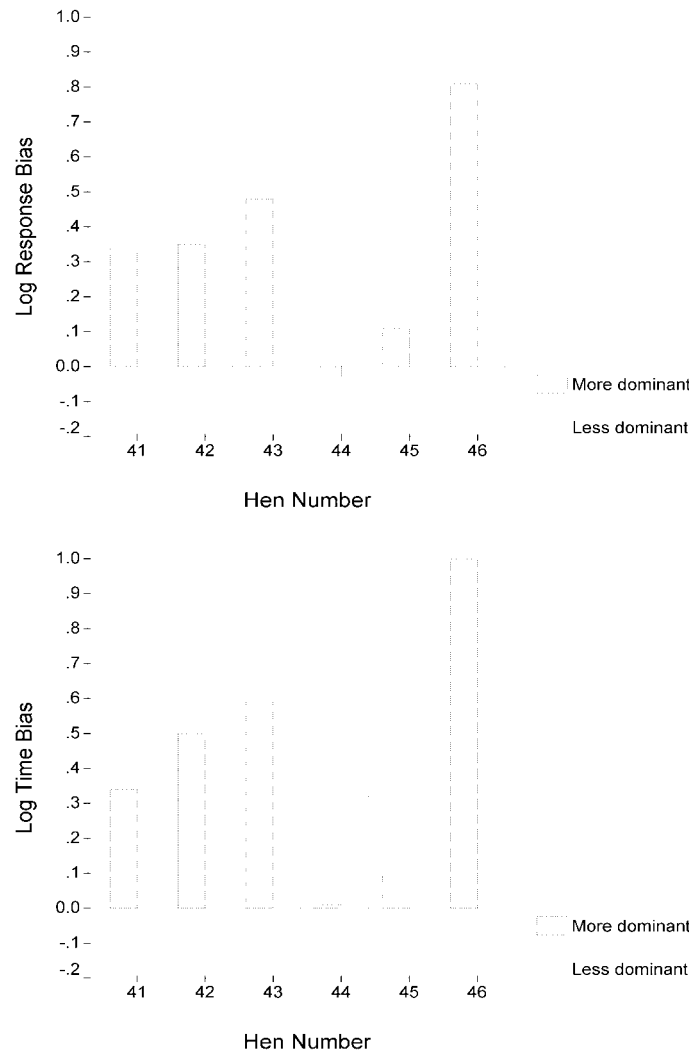


Figure 8. The logarithmic response and time bias estimates obtained when each hen in Sycamore’s (2001) study was paired with a more dominant and less dominant hen from the subject group. Because Hen 43 was the most dominant hen in the group, she was paired with two hens that were lower in the dominance hierarchy (third and fifth). Hen 45 was the least dominant in the group and was paired with two more dominant hens in the dominance hierarchy (second and fourth). In both cases, the more dominant of the target hens is labelled the “more dominant”.

Interestingly, Sycamore’s data confirmed earlier results obtained in our laboratory by Van der Plas (1991) under a free-access procedure. Van der Plas initially recorded the social dominance relations of all her hens. Then over a series of conditions she placed none, one, or two hens in compartments at each end of a large experimental chamber. The end compartments were separated from the main chamber by a spaced wire grid. She recorded where each subject hen spent its time in the main compartment when there were no other hens in the end chambers, when one end chamber contained either a hen dominant over the subject hen or a hen over which the subject hen was dominant, and when there was a dominant hen in one end chamber and a subordinate one in the other end chamber. Her most

consistent finding was that her subject hens tended to spend more time standing or sitting near any hen rather than an empty cage and near a dominant hen rather than near a subordinate hen.

Conclusions

These data serve to illustrate the use of several different ways of assessing animals' preferences using both traditional concurrent schedules and modifications of this procedure. The concurrent, multiple-concurrent and concurrent-chain schedule procedures reported here produce consistent measures of preference (bias). These studies illustrate the application of these procedures in new ways, for example, for assessing preference between sounds and between conspecifics. The transitivity (scaling) data obtained by Matthews (1983) suggest at least ordinal scaling of concurrent-schedule preference measures for an individual animal that, in turn, allows comparison of that animal's preferences across the different consequences. Thus, they have the advantage of producing measures of the degree of preference for the consequences offered.

Although no one set of data should be interpreted in isolation, data from concurrent-schedule procedures can contribute information to the debate about the way animals view their world. While we do not think they will not replace other simpler and less expensive (in terms of time and equipment) methods of assessing which of two alternatives an animal prefers, they do provide more information in that they measure the degree to which an animal prefers one alternative over the other.

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