THE EFFECTS OF ALTERING MAINTENANCE DIET ON FOOD PREFERENCES OF HENS

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LAURA CLAIRE SCHROEDER

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Abstract

The preferences of six hens for wheat, puffed wheat and pellets were investigated using Variable Interval 60-s Variable Interval 60-s dependent concurrent schedules of reinforcement with a 2-s change-over delay and 2.5-s access to wheat on the left key or either puffed wheat or pellets on the right key. In different conditions, the hens were fed at least 15-g of each of these foods when used as their maintenance diet. The number of responses, time spent responding, and amount of food consumed were examined. Body weights were maintained at 80% ± 5% of the hens' free-feeding body weights. The results showed that when wheat was paired with pellets, there were few changes in the hens' preferences when the maintenance diet was altered, but when wheat was paired with puffed wheat, there were large changes in the hens' preferences when the maintenance diet was altered, especially when wheat was used as the maintenance diet. Preferences in this study may have been affected by the quantity of maintenance diet food provided after experimental sessions, hens being outside their target weight range and unable to complete all experimental conditions, differing levels of deprivation and satiation, and the order of experimental conditions.

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Herrnstein (1970) explains that every action an animal makes involves a choice between a variety of possible responses, so effectively, all behaviour is choice behaviour. Herrnstein noted that choice could be measured by the ratio of responses to each alternative in continuous-responding procedures (such as concurrent Variable Interval (VI) reinforcement schedules). The proportion of responses, or of the amount of time spent responding on each alternative is said to indicate the relative "value" of each alternative (Baum & Rachlin, 1969), with time spent responding being applicable to a wider range of behaviours (both discrete and continuous) than the distribution of responses (Baum & Rachlin, 1969). As the proportion of responses or response times indicate the value of the reinforcers available in each alternative, these measures may be said to be measures of an animal's preference.

Various procedures have been used to assess the relative preferences of an organism for different commodities available at a certain time. Preference assessments have been used in human studies to determine the preferences of individuals with disabilities, often with the aim of identifying effective reinforcers (Davis et al., 2009), and in animal studies to determine preferences between various options with the aim of contributing knowledge relevant to the husbandry and welfare of the animal (Jones, 2011).

The different methods used to measure preferences include single-stimulus (SS) presentation (e.g., Roscoe, Iwata & Kahng, 1999), paired-stimulus (PS) presentation (e.g., Roscoe et al., 1999; Cronin, 2012) multiple-stimulus with (MSW) or without (MSWO) replacement (e.g., DeLeon & Iwata, 1996; Cronin, 2012), free-access measures (e.g., Roane, Vollmer, Ringdahl & Marcus, 1998; Jackson, 2011), two-choice (such as T-maze) procedures (e.g., Lindberg & Nicol, 1996; Kent, 1993), and concurrent reinforcement schedules (e.g., Foster, Sumpter, Temple, Flevill & Poling, 2009). The aim of all these methods is to discover which options the person or animal will spend more time with or select more often, and thus to determine which options they prefer.

In SS preference assessments, one stimulus is presented at a time and engagement time or approach response is measured. These assessments can be effective for assessing preferences and determining preferred stimuli to be used for reinforcers, but often yield results that do not determine differences in value between stimuli presented (Roscoe et al. 1999). For example, in the study carried out by Roscoe et al. (1999), 8 participants were presented with one of 10 food items on a plate each trial, and approach responses (touching or picking up the stimulus) were recorded. The results showed that 6 of the 8 participants approached each stimulus on 100% of the trials, so it was unclear which stimulus each participant had the highest preference for.

In PS assessments, pairs of stimuli are presented at a time and only one can be selected from each pair. Each stimulus is paired with every other stimulus, and often with each stimulus on the left and right sides. The frequency with which each stimulus is chosen is recorded, and the higher the percentage of times a stimulus is chosen, the more preferred it is deemed to be. These assessments provide rank-ordered results that can distinguish between preferences for different stimuli in both humans (Roscoe et al., 1999) and animals (possums; Cronin, 2012). For example, in the study carried out by Roscoe et al. (1999), a PS preference assessment was carried out after the SS preference assessment, and the same 10 foods were presented in pairs to each of the 8 participants. The results showed differentiation of preferences between the foods for all participants, with clear high-preference and low-preference foods. Cronin (2012) carried out a PS preference assessment with possums, to determine their preferences for 8 different foods. The results of this experiment were then used to select the top 4 foods for a second PS assessment for the 4 foods that were more highly preferred. The possums had 30-s to choose a food, then 5-s access to consume the chosen food. The results of the second assessment showed that 2 possums preferred soy protein, 3 preferred Cocoa Puffs and barley, and 1 preferred rolled oats. The results also provided rank-ordered preferences for each food type for each possum.

In MSW assessments, multiple stimuli are presented at a time and stimuli selected are replaced for the next trial. The number of times each stimulus is chosen is recorded, and the stimulus chosen most often is deemed the most preferred. These assessments may not provide accurate measures of preference for all the stimuli, however, as the same stimulus may be chosen in every trial and some may never be chosen at all. For example, in the MSW experiment carried out by DeLeon and Iwata (1996), 7 participants were each presented with 7 stimuli, and when a participant selected an item they were allowed 30-s to engage with it, then it was returned to the array (or a replacement of an edible stimulus was added to the array of stimuli). The results showed that 2 participants selected only 2 different stimuli, and 25 items were never chosen at all.

In MSWO preference assessments, multiple stimuli are presented and when a stimulus is chosen it is removed for future trials. These assessments have been shown to provide measures of preferences that identify effective reinforcers for both humans (DeLeon & Iwata, 1996) and animals (Cronin, 2012). In these assessments, preference can be determined by awarding points to each stimulus (with the highest number of points awarded to the first stimulus chosen and the lowest number of points to the last stimulus chosen), and the number of points awarded to each stimulus is converted to a percentage of the maximum amount of points possible if the stimulus had been chosen first each time (Cronin, 2012). MSWO assessments yield rank-ordered results and can be very time-efficient. Cronin (2012) carried out a MSWO assessment after the PS assessment, where the 4 foods were all presented to each possum, and after 1 had been selected and 5-s had elapsed, the food container was removed and the remaining 3 foods were rotated to a new position and presented to the possum again. This occurred until all foods had been chosen. The results showed that 4 of 6 possums displayed similar preference hierarchies to those found in the PS assessment.

In free-access assessments, many stimuli are available at one time, and engagement times or amount consumed are recorded as measures of preference for both humans and animals. Free-access assessments can be quickly carried out but may not yield rank-ordered results and differentiate between preferences for different stimuli. Jackson (2011) used a free-access procedure to determine hens' food preferences between wheat, puffed wheat, and commercial pellets. Hens were provided access to all of these foods for 24 hours, and the weight and volume of each food consumed were measured. The food with the highest weights and volumes consumed was deemed the most preferred. The results of the preference assessment showed that 3 hens consumed the highest volume and weight of wheat, showing that they preferred wheat to puffed wheat and pellets. One hen consumed the highest weight and volume of pellets, suggesting that she preferred pellets to wheat and puffed wheat. Two consumed variable amounts of all foods, showing no preference for any given food. While this assessment was fairly quick to carry out (14 days), the results showed no clear preferences for 2 hens so this assessment was not effective at assessing the preferences of these hens.

Two-choice procedures require the animal to make a response, which results in one type of reinforcement only. For example, in Kent's (1993) study, three-day old chicks were given a choice between a regular maternal "cluck" and a cluck altered by frequency. The chicks could turn down one arm of a T-maze, towards the normal cluck or turn down the other arm of the T-maze, towards the altered cluck. Preference was measured by the percentage of times a chick chose each side, and the results showed that the chicks preferred the normal cluck to a cluck frequency that was increased or decreased by 33%. Two-choice procedures are limited, however, in that the animal is not required to sample all options available so may only experience one, resulting in limited measures of preference that may not distinguish between preferences for one stimulus over another.

One method used to present two choices involves concurrent schedules of reinforcement. Under these schedules, the subject is required to "choose" to respond on one of two or more manipulanda that cannot be responded on simultaneously, such as plates (Matthews & Temple, 1979), levers (Martin, 2002) or keys (Foster et al., 2009). Because the animal cannot respond on both manipulanda at the same time, preference between the reinforcers available on each manipulandum can be measured by the time allocated to each manipulanda (Baum & Rachlin, 1969), and the frequency or number of responses allocated to each manipulandum (Foster et al., 2009). For example, Matthews and Temple (1979) assessed the food preferences of cows using concurrent VI schedules of reinforcement, where the cows were required to press plates with their muzzles to produce access to different types of food. The plates were far apart so the cows could only press one at a time to access either chopped hay on one side or dairy meal on the other side.

The preference measure used for concurrent schedules is based on the Generalised Matching Law (GML). This provides a mathematical equation to assess performance on concurrent VI schedules, resulting in measures of bias and sensitivity that are used to determine the preferences of organisms. The GML assesses the relationship between the proportion of responses on each schedule and the reinforcers earned (Baum, 1974). Mathematically, its form is given in Equation 1:

$$\log (B1/B2) = a \log (R1/R2) + \log c \qquad (1)$$

where B equals the time spent responding or number of responses made, R is the number of reinforcers obtained, and 1 and 2 refer to each schedule alternative. In this equation log *c* is the measure of bias, or the preference to respond on one alternative more than another regardless of reinforcement rate, and *a* is the subjects sensitivity to changes in reinforcement rate. When values of *a* are equal to 1.0, strict matching is said to occur. When values of *a* are greater than 1.0, overmatching is said to occur (Baum, 1974), and an organism has responded on the richer reinforcement alternative more than predicted by strict matching. Baum (1974) also described values of *a* that are less than 1.0 as undermatching, indicating that an organism has responded on the leaner reinforcement schedule more than was predicted by strict matching. Undermatching has been found in many species when working on equal concurrent VI VI schedules including cows (Matthews & Temple, 1979) and goats (Foster, Matthews, Temple, & Poling, 1997). Undermatching has also been found to occur in pigeons when reinforcer duration is varied (Ettinger, McSweeney & Norman, 1981), and in cows both when food types are different and when food types are the same (Foster, Temple, Robertson, Nair, & Poling, 1996).

Log c assesses the degree to which the animal responds consistently more on one alternative than the other, termed bias (Baum, 1974). Bias can be inherent (when responding differs even when the reinforcers are the same) or due to differences in the reinforcers (Foster et al., 1996). Experimentally manipulated bias can be quantified using the GML, so that once the inherent bias is removed, the only bias that remains is an indication of preference (McAdie, Foster, & Temple, 1996). Matthews and Temple (1979) adapted the GML to measure both inherent bias and bias due to different food types, and the formula is given in Equation 2:

$$\text{Log } (B1/B2) = a \log (R1/R2) + \log b + \log q \qquad (2)$$

where log b is the inherent bias, log q is the bias due to the different food types or preferences between them, log b + log q equals log c in Equation 1, and the other parameters are as defined earlier. Matthews and Temple (1979) found that this equation described preference data well, and showed that it can be used when analysing preferences for qualitatively different reinforcers. Inherent bias assessments can be carried out to determine bias for responding on a particular side, in order to calculate accurate preference measures (Foster et al., 2009). To assess inherent bias, in one condition of the study carried out by Foster et al. (2009), hens responded on concurrent Random-Interval (RI) 90-s RI 90-s reinforcement schedules with a 2-s change-over delay (COD) for wheat in both magazines. Inherent biases were found for all hens toward the right key, and these values were subtracted from bias measures in other conditions to determine the bias that was due to different food types. The biases in responses attributed to the different food types showed that wheat was the most preferred food, then honey-puffed wheat, and puffed wheat the least preferred.

Concurrent schedules of reinforcement have been used to assess the relative preferences of many species such as humans (Lie, Harper, & Hunt, 2009), cows (Matthews & Temple, 1979), domestic hens (Foster et al., 2009; Bruce, 2007), goats (Foster et al., 1997), pigeons (Hollard & Davison, 1971), and possums (Bron, Sumpter, Foster, & Temple, 2003). They are commonly used to assess relative preferences between two or more commodities such as qualitatively different foods (Foster et al., 2009), brain stimulation and food (Hollard & Davison, 1971), and different litter substrates (Harris, 2006). Hollard and Davison (1971), for example, examined pigeons working under concurrent VI VI reinforcement schedules for food on one key and for ectostriatal brain stimulation on the other key. Brain stimulation was kept at VI 1-min, while food reinforcement schedule was varied from VI 0.5-min to VI 10-min. Time and response allocations showed the pigeons preferred food over the brain stimulation.

Typically, in these studies, equal VI concurrent schedules of reinforcement are used when assessing the relative preferences of animals. When working under VI reinforcement schedules, reinforcement is available on each key following the first response after an average amount of time has passed since the previous reinforcer was delivered (Ferster & Skinner, 1957). For example, during a VI 30-s reinforcement schedule, reinforcement is delivered after the first response that was produced after an average of 30 seconds. Equal VI concurrent schedules (such as VI 30-s VI 30-s) are often used and the animals are likely to respond on both schedules in order to maximise the number of reinforcements available, so will sample both the types of reinforcers instead of just one.

Concurrent schedules can be programmed either independently or dependently. When schedules are independent, reinforcement on one alternative does not affect the availability of a reinforcer on the other alternative (Herrnstein, 1961). This can be problematic as the animal is not required to respond on both alternatives, and preference may be exclusive to one alternative (Sumpter, Foster, & Temple, 2002). To overcome this problem, schedules are often arranged dependently, where the availability of a reinforcer on one schedule inactivates the timer of the other schedule until the reinforcer is collected (Stubbs & Pliskoff, 1969). Dependent schedules therefore require the animal to sample both alternatives, and exclusive choice is prevented. Dependent schedules may, however, result in preference measures smaller than the animal's actual preferences (Matthews & Temple, 1979). Most preference studies using concurrent schedules programme the schedules dependently.

Variable Interval concurrent schedule procedures also generally incorporate a COD. A COD is a specified period of time that occurs after a reinforcer is delivered on one schedule and the animal begins responding on the alternate schedule, where no reinforcer may be delivered on that schedule (Herrnstein, 1961). COD's prevent rapid alternating between schedules, and result in the closer matching of relative response rate to relative reinforcement rate (Herrnstein, 1961). It has been argued that the size of COD required to separate the schedules may differ across species. Temple, Scown and Foster (1995) suggested that a COD of 2-3-s in length was sufficient to allow separation of the schedules for hens.

All the methods of preference assessments mentioned above have been shown to give information on the relative preferences of people with disabilities, and/or, animals. The information provided by each type of assessment and its reliability differ across methods. SS assessments have been shown to be less reliable in measuring preferences than PS procedures as participants may approach or engage with all stimuli equally during SS assessments (Roscoe et al., 1996), but SS procedures could be used to gain a general idea about preferences rather than to determine rank-ordered preferences. PS procedures may be very reliable in measuring preferences and yield rank-ordered results, but may require long periods of time to carry out, as many combinations of pairs are required. MSW procedures have been shown to reliably measure preferences only to a limited degree as some stimuli presented are never chosen (DeLeon & Iwata, 1996), yet they are fast procedures to carry out. MSWO procedures have been effectively used to measure preferences, include rank-ordered results, and have been shown to yield similar results to PS methods (Cronin, 2012), yet can take a considerably shorter time to carry out (DeLeon & Iwata, 1996). Free-access assessments may also be quick to carry out, but may not provide clear distinctions between preferences for different stimuli (Jackson, 2011). Two-choice procedures have also been used to assess preferences, but subjects may not be required to sample all alternatives available, so may respond on one choice only, resulting in potentially different preference measures than if the subjects had sampled both alternatives. Concurrent schedules of reinforcement have been used to measure preferences, and when schedules are dependent, subjects are required to sample both options available. However, if a schedule is not responded on when reinforcement is due on that side while dependent schedules are in effect, the subject is unable to receive the reinforcer available on the other side, potentially resulting in the subject not earning all the reinforcers available and limiting the assessment of preference. All these procedures measure preference at one place and time, and the preferences resulting depend on what choices are available and the subjects' experiences with the stimuli being used. The type of preference assessment selected depends on the aims of the investigation. Since preference is not "fixed", the different variables that influence it need to be examined.

As Sumpter et al. (2002) noted, the preferences of animals and humans can be affected by factors other than the stimuli being presented in preference assessments, such as the presentation of stimuli outside of experimental conditions (Gottschalk, Libby, & Graff, 2000), and body weight (Ferguson & Paule, 1997). These factors that affect the reinforcing value of a commodity, such as food deprivation making food more reinforcing, are called establishing operations (Michael, 2000). Establishing operations not only alter preferences, but have been manipulated to alter many behaviours, such as providing access to attention to decrease the rates of problem behaviour (e.g., hitting and bizarre speech) of individuals with developmental disabilities (O'Reilly et al., 2008; Rispoli et al., 2011), training children with autism to initiate joint attention with an adult (Naoi, Tsuchiya, Yamamoto, & Nakamura, 2008), and altering stimulus control in rats and pigeons (Lotfizadeh, Edwards, Rednor, & Poling, 2012).

Deprivation and satiation have been shown to be establishing operations that affect the preferences of individuals with intellectual disabilities for different foods (Gottschalk et al., 2000) as well as different toys (McAdam, Koffarnus, Dicesare, Welch, & Murphy, 2005). In the study carried out by Gottschalk et al. (2000), participants completed a PS presentation preference assessment for different foods. Approach response was recorded under each of three conditions: control (limited access to stimuli over the 24 hours prior to experiment), satiation (regulated access to all stimuli with 10 minutes of free access to one stimulus over the 24 hours prior to the experiment) and deprivation (limited access to three of four stimuli over the 24 hours before the assessment, and no access to the fourth stimulus 48 hours before the assessment). The results showed higher levels of approach responses by most participants after deprivation than after both the control and satiation conditions for the majority of stimuli presented, and lower responses after satiation than for the other conditions for most stimuli presented. In the studies carried out by Gottschalk et al. (2000) and McAdam et al. (2005), only short-term deprivation and satiation conditions were investigated (24 to 144 hours) and it is unclear whether these preferences would remain stable if longer-term satiation or deprivation conditions were investigated.

Altering body weight has been shown to affect rats' motivation for food (Ferguson & Paule, 1997; Hodos, 1961), showing that body weight is an establishing operation that changes the value of food for the animals. Ferguson and Paule (1997) investigated the effects of manipulating body weight on the response rate of rats pressing a lever on a Progressive Ratio (PR) of 1 reinforcement schedule, with rats at 75%-100% of their free-feeding body weight. The results showed that PR behaviour varied significantly due to differences in body weight, with the response rates, and subsequently the number of reinforcers earned, decreasing with increasing body weight. These results show that body weight affects animals' responding, and should be controlled in preference assessments for food.

Food restriction is another establishing operation that can increase motivation for food. Bokkers, Koene, Rodenburg, Zimmerman, and Spruijt (2004) investigated the motivation of broiler chickens to peck a key to gain food on PR2 and PR4 schedules, when fed either 50% or 75% of the amount the broilers would eat when free feeding. The results showed that broilers in the 50% group paid a higher price (in key pecks) for food than the 75% group in the first test week, and showed higher motivation in the second week, but not significantly. Short-term changes in food restriction (changing from 50% to 75% and vice versa for one day of testing) did not affect the broilers' responses, highlighting the necessity of longer-term food restriction conditions.

Contrary to the research mentioned, food deprivation has also been shown to have little effect on hens' motivation to work for food when the food reward is highly reinforcing (Bruce, Prescott, & Wathes, 2003). These authors found that hens worked to the same maximum Fixed Ratio (FR) value for maggots (the food found to be most highly preferred in a previous preference assessment) when they were both food deprived and non-food deprived. This suggests that some foods may be so highly reinforcing that food deprivation does not act as an establishing operation for motivation to work for these foods.

It has been proposed that altering an animal's maintenance diet may function as an establishing operation affecting the value of the food (Jackson, 2011). In Jackson (2011), the preferences of hens for wheat, puffed wheat, and pellets were assessed using a free-access measure. The hens' maintenance diets were then altered (again using wheat, puffed wheat and pellets), and hens completed a demand assessment using FR and PR schedules for the different food types. Demand assesses the way the animal's consumption of a commodity changes as the price is increased, and also assesses the price at which its consumption drops (Hursh, 1980). Demand assessments are often used to examine preference. If an animal will work harder for a reinforcer preferred by the animal than for a reinforcer deemed less preferred, the preference assessment is probably accurate. In Jackson's (2011) experiment, the results of the preference assessment showed that 3 hens preferred wheat, 1 preferred pellets, and 2 showed no preference. The results of the demand assessment showed that, contrary to the hypothesis, maintenance diets had no significant effect on the hens' demand for different food types. Therefore, it is still unknown whether an animal's maintenance diet will act as an establishing operation for an animal's demand or preference for different food types.

Providing free access to a reinforcer before or during experimental sessions can decrease an animal's motivation to work for that reinforcer (Podlesnik & Shahan, 2009). In the experiment carried out by Podlesnik and Shahan (2009), rats were required to press levers on concurrent VI 60-s VI 60-s schedules of reinforcement for either pellets available for pressing a lever on one side of the experimental chamber, or sucrose solution for pressing the lever on the other side of the chamber. Free access to sucrose solution or pellets was provided before or during sessions. The results showed that free access for a type of reinforcer decreased responding, and therefore preference, for that type more than responding for the other type of reinforcer. If access to reinforcers within experimental sessions can affect preferences, then access to reinforcers outside of experimental sessions may also affect preferences.

Most of the research found investigating establishing operations has been conducted using single schedules of reinforcement, with the studies investigating the effects of manipulating establishing operations on demand for reinforcers. It is possible that establishing operations may affect animals' preferences between food that is provided as part of their maintenance diet and other foods, and this could be investigated using concurrent schedules of reinforcement. Jackson's (2011) study is the only research that could be found that has investigated the effects of altering maintenance diets on demand for different food types with hens. Jackson (2011) used hens as subjects, and the results failed to show that altering the hens' maintenance diets acted as an establishing operation for motivation to work for food. The present experiment aimed to investigate whether or not altering hens' maintenance diet will function as an establishing operation for food preferences.

As dependent, equal VI concurrent schedules have been used to measure food preferences of animals previously (e.g., Foster et al., 1996), they were used in the present experiment to measure the hens' relative preferences for wheat (W), puffed wheat (PW) and commercial laying pellets (P), when provided these foods individually outside of the experimental sessions as their maintenance diets. In the current experiment, the economy was required to be open, meaning that the hens were provided with at least some of the specified feed outside of the experimental conditions. Body weight as an establishing operation was controlled by maintaining the hens at 80% ± 5% of their free-feeding body weights, and not placing them in experimental sessions if they were outside of this weight range. Inherent bias was assessed initially to ensure that the biases calculated as measures of preference were measures of bias due only to the different food types.

If maintenance diet acted as an establishing operation for food preference, it would be expected that the hens' preferences for the different food types would change when the maintenance diet was changed.

Method

Subjects

The subjects in this experiment were 6 Brown Shaver hens (*gallus gallus domesticus*), numbered 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6. They were approximately two years old at the beginning of the experiment. Hens 4.1 to 4.5 had prior experimental experience pecking a computer screen to gain food reinforcement, and Hen 4.6 had prior experimental experience pecking a key to gain food reinforcement. The hens were maintained at 80% ±5%, of their free-feeding body weight throughout the experiment by supplementary feeding of the maintenance diet (either commercial poultry pellets, wheat or puffed wheat) after experimental sessions. The 80% free-feeding body weight was determined by calculating 80% of the hens' average daily weight over a period of 22 days, during which they had free access to food (poultry pellets). The hens were weighed daily and provided with supplementary vitamins and grit weekly. They were housed individually in cages 310-mm high by 440-mm wide by 450-mm deep, and had unlimited access to water. Hens were placed in experimental sessions only if their weight was equal to or within 80% ±5% of their free-feeding body weight, and were always fed at least 15 g of their maintenance diet food type each day after experimental sessions were completed. If underweight, the hens were fed 5 g more each day until their target weight was achieved, and if overweight, they were fed 5 g less than the previous day. On occasions where the hens earned less than 32 reinforcers, hens were fed extra to maintain their target body weight.

Apparatus

The experimental chamber measured 620-mm long by 580-mm wide, by 540-mm high. The interior was painted matte white and a plastic mat was placed on the floor. Two round response keys (30-mm diameter) made from translucent Perspex were mounted 19-mm apart on the right-hand wall of the chamber. The keys had backlights that could be illuminated green, and were situated 330-mm above the chamber floor. Each effective key peck required a force of at least 0.1N to close a micro-switch behind the key, and was followed by a brief audible beep.

Beneath each key there was an opening measuring 100-mm high by 70-mm wide, where the food hopper was raised to for 2.5-s during reinforcement. Two sensors were located at the opening of the food hopper, one on the left and one on the right, which detected when a hen's head was in the food hopper opening. The opening was lit with a white light when the hopper was raised, and the key lights were extinguished during reinforcement. When either hopper was raised both keys were dark and inoperable. Each hopper was attached to a magazine filled with one of the foods used in that condition (wheat always in the left hopper, and either puffed wheat or pellets in the right hopper). Each magazine was rested on Sky Jadever Precision Balance® digital scales outside of the chamber, and the weight of food was measured before and after each experimental session to determine the weight of food consumed during each session. A minimum of five consecutive stable weight readings were required on both scales at the same time for each experimental session to begin. A tray was also placed beneath the magazines to collect spilt food, and that food was weighed and not included in the weight of food consumed.

The magazines, scales and power supply were attached to a computer, in the same room as the chamber, running a MedPC program that recorded the experimental events.

Procedure

Training

Each hen had prior magazine training from previous experiments, so at the beginning of training each hen was placed in the experimental chamber with the key lights extinguished. The left magazine was filled with wheat and was raised until the hen ate from it for 3-s, then it was lowered. The right magazine, also filled with wheat, was then raised until the hen ate from it for 3-s, then it was lowered. Both key lights were then lit and the hens' key pecking responses were then shaped through reinforcing successive approximations. The reinforcer was 3-s access to the wheat once the hens were reliably pecking the lit keys. The keys were then lit individually until the hen had pecked both of them, to ensure the hens reliably pecked both left and right keys.

Hens then responded on concurrent VI 5-s VI 5-s schedules for reinforcement, meaning that reinforcement became available for a response on a key after an average of 5-s since the last reinforcer. The VI values used came from a list of 15 numbers with an average of 5-s, randomly arranged, and the computer program randomly selected which interval to start with, continuing the list from that number. The schedules were programmed dependently, meaning that when a reinforcer became available on one key, the VI timer on the other key stopped counting down until the hen obtained the due reinforcer. For example, if a reinforcer was due on the left key, the time until a reinforcer was due on the right key did not decrease until the reinforcer on the left key had been obtained. Once the 3-s reinforcement had concluded, the right VI timer continued counting down the time until the next reinforcer was due on the right, and the next interval started on the left VI timer until a reinforcer was due on the left again. A 1-s COD was then put into effect, meaning that after a reinforcer was delivered on one schedule, 1-s must have elapsed before responding on the alternate schedule could produce a reinforcer, ensuring the hen was not reinforced simply for switching keys. The

VI value was then increased on both schedules to 10-s, and then the COD was increased to 2-s. The VI value was then increased to 30-s, then 45-s, then 60-s.

Due to the necessity of maintaining the hens' target body weights and the hens always receiving post-experimental feed, the reinforcer time was decreased after training from 3-s to 2.5-s to ensure hens did not become overweight. During Condition 4, however, Hen 4.5 gained weight to the point of being too heavy for the experimental sessions. Her post-feed on days she was overweight was reduced from 30 g to 20 g.

Bias assessment

During the bias assessment (Condition 1, W vs W/ P), hens responded on dependent concurrent VI 60-s VI 60-s schedules of reinforcement for 2.5-s access to wheat in both magazines. At the start of each session, the hen was placed in the experimental chamber and either the left or the right key light was lit initially. The order the keys were lit was determined randomly by the MedPC program in use. Once the hen had pecked the first lit key, the key light was extinguished and reinforcement was delivered. The alternate key light was then lit until the key was pecked, and reinforcement was delivered again. This procedure was used to ensure the hens sampled the food alternatives available in both magazines. Both keys were then lit and the VI 60-s VI 60-s schedules were in effect with a 2-s COD for the remainder of the experimental session. Experimental sessions ended after 32 reinforcers were earned or 40 minutes had elapsed, whichever occurred first. Responses, time spent responding on each key, number of reinforcers earned on each key, the weight of food consumed, and eat time (the time spent with head in the magazine) were measured.

After ten sessions, the magazines were switched so the left magazine was place on the right hand side, and the right magazine was placed on the left hand side to determine whether or not any bias found was due to the side of presentation of the magazine.

Preference assessment

Hens were fed pellets in their home cages as their maintenance diet before the experiment commenced. At the start of each experimental session, a hen was placed in the experimental chamber. As in the bias assessment, one of the keys was lit (determined randomly), and the key light was turned off when the hen pecked the key and was reinforced. The other key was then lit and remained illuminated until pecked, which resulted in a reinforcer delivery. This ensured the hens sampled both reinforcers at the start of an experimental session. After this second reinforcer delivery, the hens then were required to respond on dependent concurrent VI 60-s VI 60-s schedules of reinforcement with a 2-s COD over several conditions. Hens responded in each condition until visual and statistical stability was achieved. Statistical stability was achieved when the median of the last five values of the proportion of responses on the left key was within 0.05 of the value of the median calculated for the five sessions prior. This measure was required for five, not necessarily consecutive, sessions. Once statistical stability was reached, the log ratios of responses were plotted against sessions, and the graph was visually examined. Visual stability was reached if the data were deemed not to be trending in any direction, as evaluated by at least two lab members.

In Condition 2 (W vs PW/ P), pellets were used as the hens' maintenance diet, and the hens responded on the left key to produce 2.5-s access to wheat, and on the right key to produce 2.5-s access to puffed wheat. In Condition 3 (W vs P/ P), each hen was fed pellets as their maintenance diet, and responded for wheat on the left key and for pellets on the right key. The maintenance diets were then altered to puffed wheat, and the hens responded firstly to produce wheat on the left key and pellets on the right key (Condition 4, W vs P/ PW), then to produce wheat on the left key and puffed wheat on the right key (Condition 5, W vs PW/ PW). Despite being fed the amount of food to maintain her body weight, Hen 4.1 was too underweight to complete the condition, so stable data from earlier in the condition were used in analysis for this hen and she progressed to Condition 6 to allow the remainder of the hens to progress. In Condition 6 (W vs PW/ W), wheat was used as the maintenance diet, and the hens worked for wheat on the left key and puffed wheat on the right key. Due to being underweight again, no stable data were recorded for Hen 4.1 during this condition. In Condition 7 (W vs P/ W), wheat was used for the maintenance diet, and the hens worked for wheat on the left key and pellets on the right key. Due to 4 hens ceasing to respond on the left side of the concurrent schedule for W, and 2 of these hens consistently being outside of their weight ranges, Condition 7 ended when the data from the remaining 2 hens were both visually and statistically stable. In Condition 8 (W vs P/ P*), the hens responded for the same foods and were fed the same maintenance diet as in Condition 3 (W vs P/ P). After each experimental session the hens were fed at least 15 g of maintenance diet food.

During Condition 5, it became clear than Hen 4.1 was not consuming all of her W post-feed, and was spilling a proportion of it outside of her home cage. At this point, her feed container was replaced with a large one so feed could not be easily spilled, and the weight of food left over was weighed each morning to determine the weight of food she was actually consuming. The same occurrence was noted for Hen 4.3 during Condition 7 and Hen 4.4 during Condition 8, so these hens' feed containers were also replaced with larger ones, and the left over food was weighed each morning.

Table 1.

Sequence of experimental conditions, abbreviations of conditions and the number of sessions completed for each condition.

Condition Number	Condition Abbreviation	Left Food	Right Food	Maintenance Diet	Number of Sessions
1	W vs W/ P	Wheat	Wheat	Pellets	53-54
2	W vs PW/ P	Wheat	Puffed wheat	Pellets	21
3	W vs P/ P	Wheat	Pellets	Pellets	25-27
4	W vs P/ PW	Wheat	Pellets	Puffed wheat	24-36
5	W vs PW/ PW	Wheat	Puffed wheat	Puffed wheat	19-24
6	W vs PW/ W	Wheat	Puffed wheat	Wheat	22-24
7	W vs P/ W	Wheat	Pellets	Wheat	24
8	W vs P/P*	Wheat	Pellets	Pellets	22-42

Results

The data from the last five sessions of each condition for each hen were used in all analyses and are given in Appendix A. All ratios of responses, time spent responding, or volume of food consumed, are expressed as the left side measure over the right side measure. Raw data, figures, spreadsheets and programs used are given in Appendix C.

Hen 4.1 completed only Conditions 1-4 and Condition 8. This hen's weight fell below the minimum constraints of her target weight range, and as a consequence of concerns over the animal's welfare, her maintenance diet was changed during Conditions 4 and 5 from PW to P, and in Conditions 6 and 7 from W to P. Hens 4.2, 4.3 and 4.4 completed only Conditions 1-6 and Condition 8. Due to Hen 4.3 being consistently below the minimum constraints of her target weight range during Condition 7, her maintenance diet food was changed from W to P. Pellets are a more complete diet and it was hoped this would help maintain the animal in its target weight range, which it did. During Condition 7, Hens 4.2 and 4.4 ceased to respond on one side of the concurrent schedules and no stable data were collected. Hens 4.5 and 4.6 completed all conditions.

After the first 10 days of testing, the hens all had biases for the left side over the right side, even though both magazines contained W. To check whether these biases were from the magazines, the side of each magazine was changed. Biases remained approximately the same despite this change, so these data are not presented.

Figure 1 shows the log ratios of responses of each hen plotted for each of the last five sessions of Conditions 1-8. Data points above zero on the y-axis indicate a higher proportion of responses on the left key, and data points below zero on the y-axis indicate a higher proportion of responses on the right key.

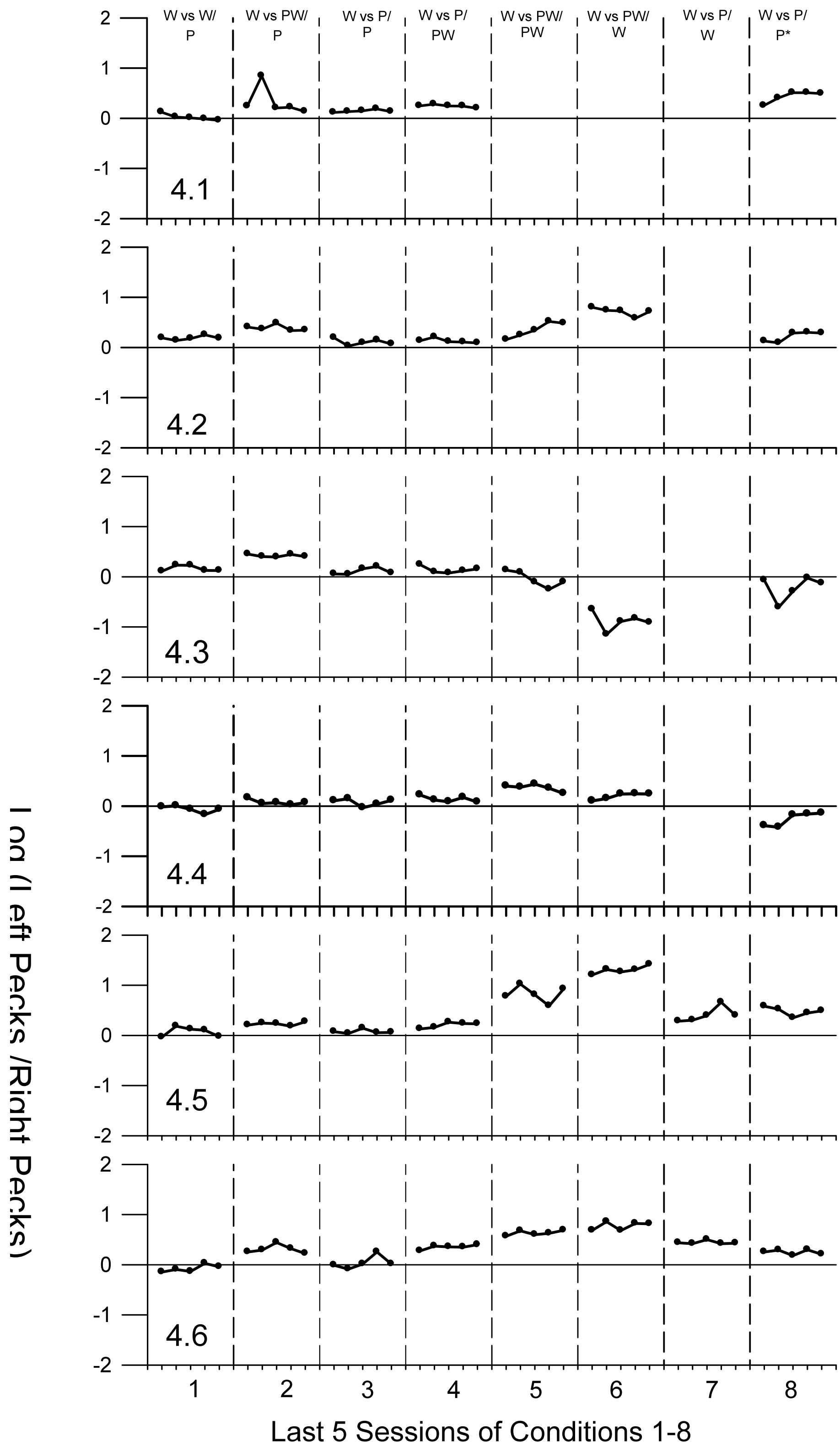

Figure 1. Log ratios of responses on each key plotted for each of the last five sessions for each hen for Conditions 1-8. Note that W- wheat, PW- puffed wheat and P- pellets.

During Condition 1 (W vs W with P maintenance diet), 3 hens responded more on the left key than the right, 2 hens responded more on the right key than the left, and 1 hen responded about the same on each key. In Condition 1, pecking both keys resulted in W, so the proportion of pecks on one side compared to the other would reveal any inherent bias or log *c* (Equation 1) for the left or right key. The data show that 3 hens had inherent biases for pecking the left key, 2 hens showed biases for the right key, and 1 hen showed no bias. The exact values of these biases range from -0.08 to 0.19 and are shown in Table 2. Table 3 shows the biases of the hens for time spent responding on each key, with the loc *c* values ranging from -0.14 to 0.21. These values indicate that the hens had the same biases for each key as the log *c* values for the proportion of pecks (Table 2) except for Hen 4.5, whose log *c* value for the proportion of time spent responding indicates a very small bias towards the left key.

Figure 1 shows that in Condition 2 (W vs PW/P), the log ratio of responses increased for all hens as compared to Condition 1, with proportionally more responding on the left key. Equation 2 was used to give the estimates of log *q*, the bias due to the different food types, for Conditions 2-8. These are shown in Table 2 and Figure 2. In Condition 2, when the maintenance diet was P, the values of log *q* show preferences towards W for all hens when PW was available following responses to the right key.

In Condition 3 (W vs P/P), the log ratio of responses decreased slightly for 5 hens, and remained about the same for 1 hen, compared to Condition 2 (Figure 1). Figure 2 and Table 2 show that 4 hens preferred W to P when the maintenance diet was P, but the preference for W was greater for these hens when compared to PW (in Condition 2) than when compared to P. The remaining 2 hens preferred P to W.

Table 2.

Mean log c *(Condition 1) and log q (Conditions 2-8) values for proportion of responses by hens of the last five sessions of each condition.*

Condition Number	Condition Name	Hen 4.1	Hen 4.2	Hen 4.3	Hen 4.4	Hen 4.5	Hen 4.6
1	W vs W/ P	0.02	0.19	0.16	-0.06	0.07	-0.08
2	W vs PW/ P	0.31	0.20	0.26	0.14	0.16	0.39
3	W vs P/ P	0.12	-0.08	-0.05	0.14	0.00	0.12
4	W vs P/ PW	0.22	-0.06	-0.03	0.20	0.13	0.43
5	W vs PW/ PW		0.16	-0.21	0.43	0.75	0.71
6	W vs PW/ W		0.53	-1.05	0.26	1.2	0.85
7	W vs P/ W					0.34	0.52
8	W vs P/P*	0.41	0.03	-0.39	-0.20	0.41	0.33

Table 3.

Mean log c (Condition 1) and log q (Conditions 2-8) values for proportion of time spent responding by hens of the last five sessions of each condition.

Condition Number	Condition Name	Hen 4.1	Hen 4.2	Hen 4.3	Hen 4.4	Hen 4.5	Hen 4.6
1	W vs W/ P	0.03	0.11	0.21	-0.14	0.10	0.00
2	W vs PW/ P	0.27	0.19	0.14	0.09	0.20	0.44
3	W vs P/ P	0.13	-0.05	-0.14	0.16	0.02	0.12
4	W vs P/ PW	0.25	-0.03	-0.13	0.24	0.08	0.52
5	W vs PW/ PW		0.21	-0.15	0.44	0.57	0.67
6	W vs PW/ W		0.56	-1.31	0.18	0.87	0.74
7	W vs P/ W					0.29	0.59
8	W vs P/P*	0.50	0.01	-0.44	0.18	0.32	0.40

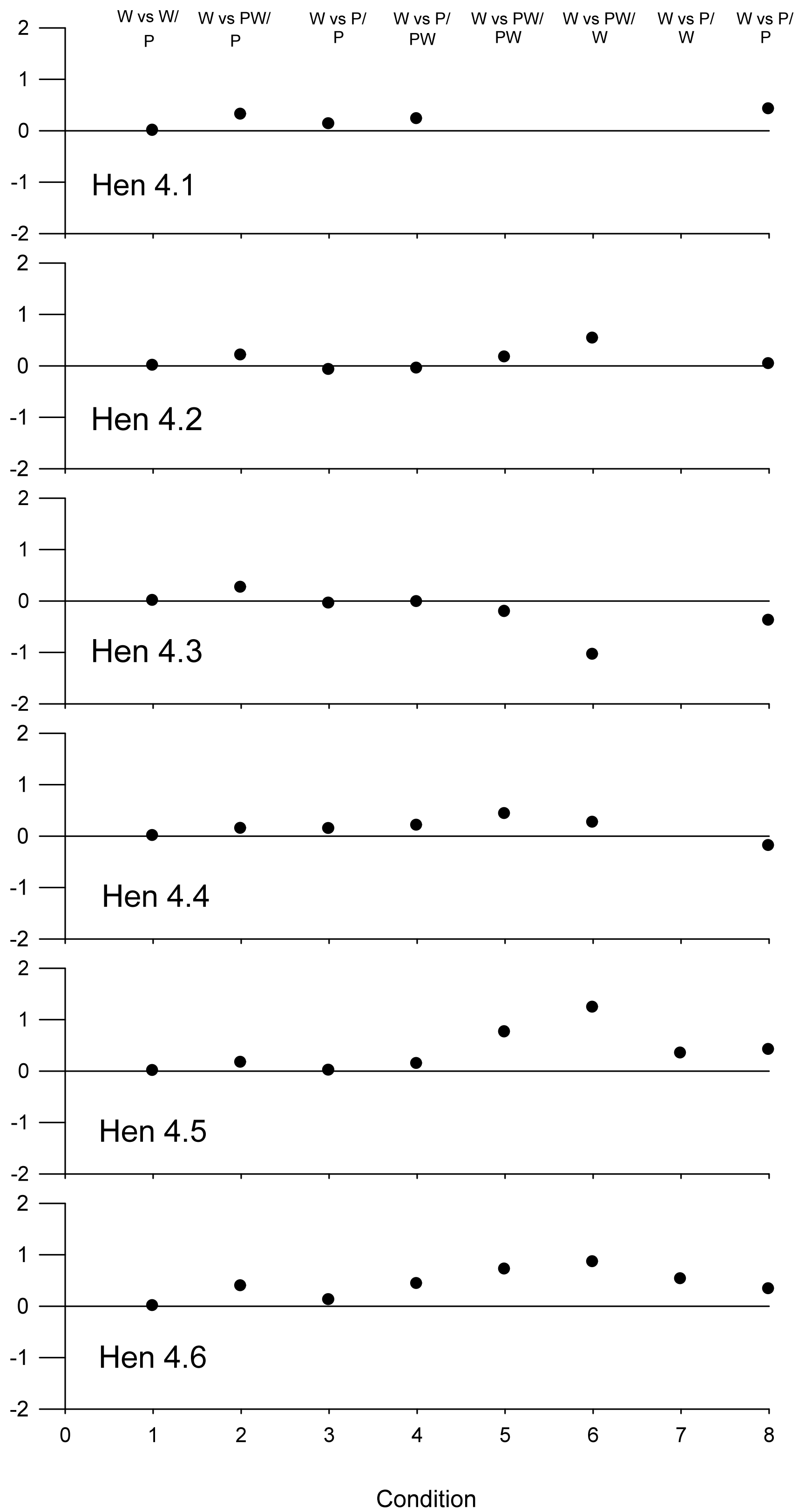

Figure 2. Mean log q of responses of the last five sessions of each condition plotted against Conditions 1-8. The data shown for Condition 1 are at zero as log q is zero in this condition. Note that W- wheat, PW- puffed wheat and P- pellets.

In Condition 4 (W vs P/PW) when the maintenance diet was changed to PW, the ratio of responses increased slightly for several hens as compared to Conditions 1-3 (Figure 1). The response biases for 4 hens increased compared to Condition 3, and for 2 hens remained about the same. Figure 2 and Table 2 show that 4 hens displayed preferences for W over P, and greater preferences for W than P when PW was the maintenance diet than when P were the maintenance diet (Condition 3).The other 2 hens displayed greater preferences for P than W, but slightly lesser preferences for P when PW was the maintenance diet than when P were the maintenance diet.

Figure 1 shows that in Condition 5 (W vs PW/ PW), the ratio of responses increased for 4 of the 5 hens compared to Condition 4, and the ratio of responses for the remaining hen decreased compared to Condition 4. Figure 2 and Table 2 show that 4 of 5 hens preferred W to PW, and all of these hens displayed greater preferences for W when PW was the alternative than when P were the alternative (Condition 4). The remaining hen showed a greater preference for PW over W, and a greater preference for PW than for P (Condition 4).

In Condition 6 (W vs PW/ W), the ratio of responses increased from those in Condition 5 for 3 of 5 hens, and decreased for 2 hens (Figure 1). Figure 2 and Table 2 show that in Condition 6, 4 of 5 hens had greater preferences for W than PW, and all of these hens had greater preferences for W compared to PW when W was the maintenance diet than when PW was the maintenance diet (Condition 5). The remaining hen displayed a strong preference for PW over W, a stronger preference for PW over W when W was the maintenance diet than when PW was the maintenance diet.

Figure 3 shows the log response ratios from each session of Condition 7. Hens were exposed to experimental sessions only when within their target weight

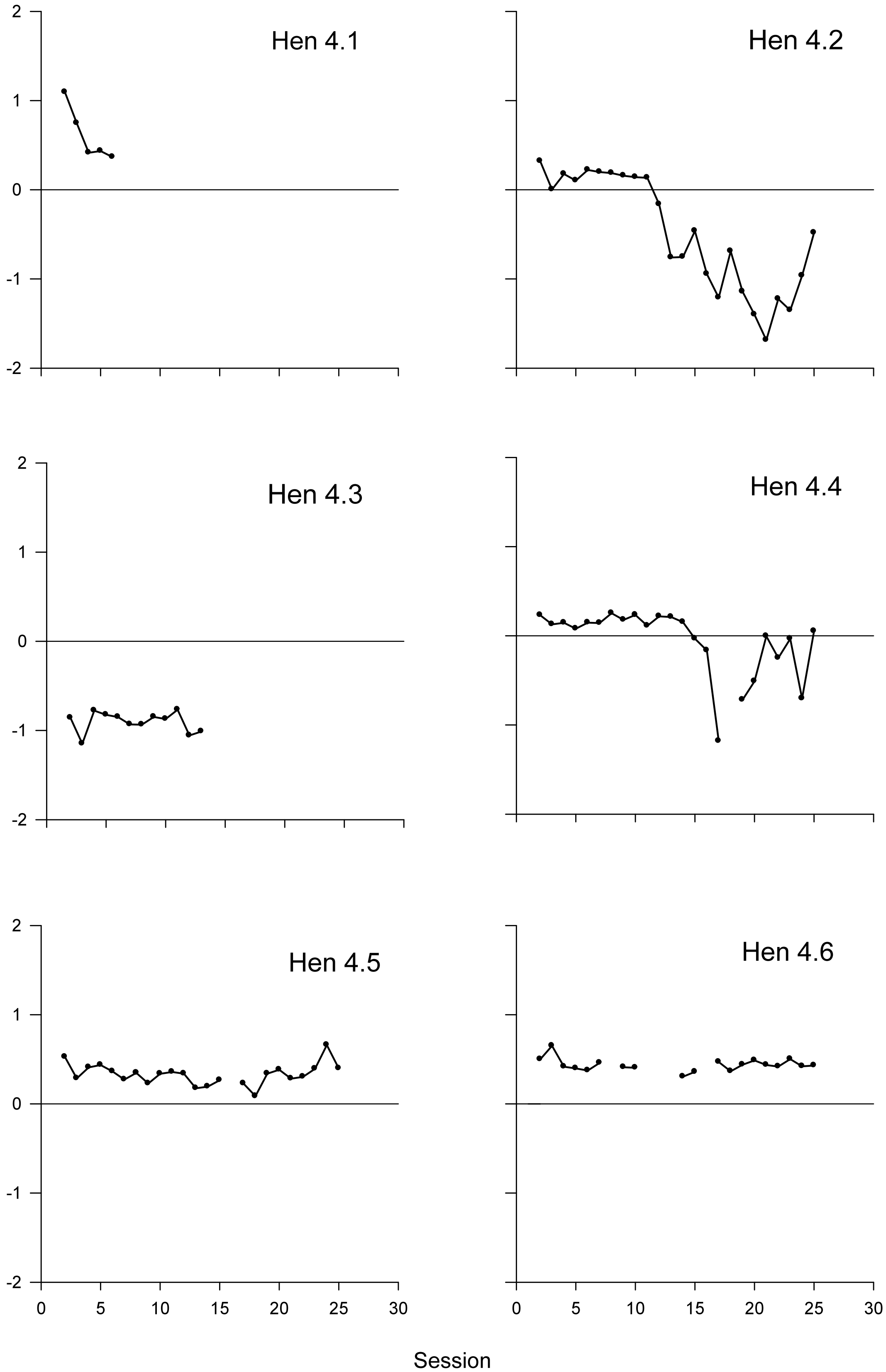

Figure 3. Log ratios of responses on each key of each hen during each session of Condition 7.

range, so gaps in the data pattern indicate days the hens did not experience experimental sessions. Hens 4.2 and 4.4 had extremely variable data and Hens 4.1 and 4.3 were outside their target weight ranges. Thus, the responding of hens 4.1-4.4 did not reach stability and these hens subsequently did not complete Condition 7. The responding of only hens 4.5 and 4.6 reached stability. Time constraints meant that it was not possible to wait until all hens were in their target weight ranges and for their behaviour to reach stability.

Figure 1 shows that in Condition 7 (W vs P/ W) the ratio of responses decreased from those in Condition 6 for Hens 4.5 and 4.6. Figure 2 and Table 2 show that in Condition 7, the 2 hens in this condition had greater preferences for W than P, but lesser preferences for W compared with P than for W when compared with PW (Condition 6).

Figure 4 shows the log response ratios from each session of Condition 8. Hen 4.2 did not complete the condition due to her ceasing to respond in experimental sessions, as can be seen by the sudden decrease in responding near the end of this condition. Stable data from earlier in the condition were, however, used in analysis for this hen. All other hens' behaviour reached stability and the log ratios of their responses in the last 5 sessions of this condition are shown in Figure 1.

In Condition 8 (W vs P/ P*), the ratio of responses decreased from those in Condition 7 for 1 of the 2 hens that completed Condition 7, and remained approximately the same for 1 hen (Figure 1). Figure 1 also shows that the ratio of responses increased from those in Condition 3 (the same experimental conditions as Condition 8) for 4 hens, and decreased for 2 hens. Figure 2 and Table 2 show that in Condition 8, 4 hens had greater preferences for W than P, and 2 hens had a greater preference for P than W. All of these preferences were larger for the hens'

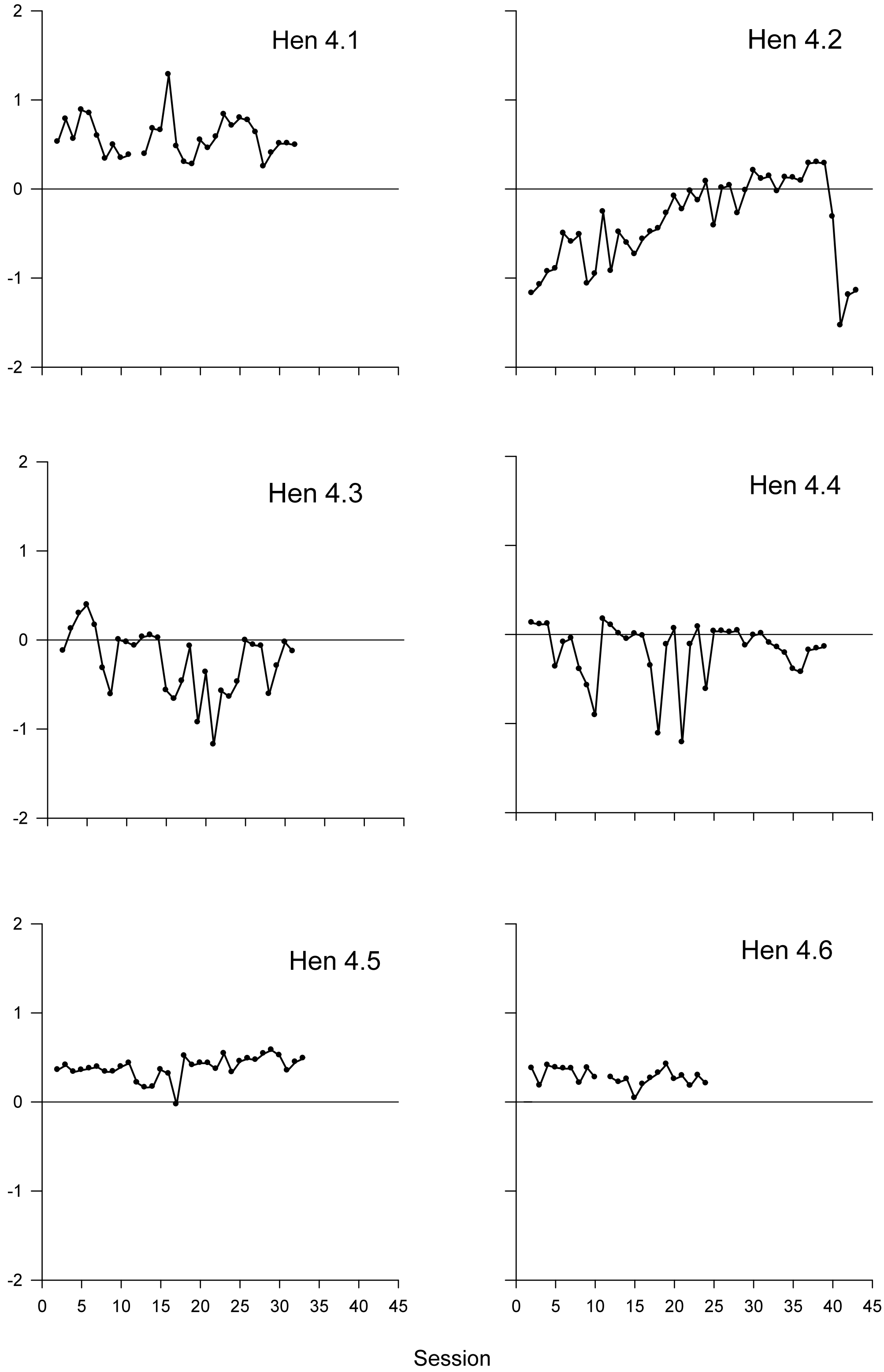

Figure 4. Log ratio of responses on each key for each hen in each session in Condition 8.

preferred foods than those in Condition 3 except for 1 hen's preference, which was approximately the same, even though the experimental conditions were the same in these two conditions.

In summary, when P were the maintenance diet (Conditions 2 and 3), all 6 hens preferred W to PW, 4 hens showed preference for W over P, and 2 hens (4.2 and 4.3) preferred P to W. For the 4 that preferred W to both foods, preference for W was larger when paired with PW than when it was paired with P. Thus all 6 hens showed PW was their least preferred food. When PW was the maintenance diet (Conditions 4 and 5), 4 hens preferred W to P, and 2 hens (4.2 and 4.3) showed small preferences for P over W. Of the 5 hens that completed Condition 5 (W vs PW), 4 hens preferred W to PW, and 1 hen (4.3) preferred PW to W. For the 3 hens that preferred W to both P and PW, preference for W was larger when it was paired with PW than when it was paired with P. Thus these hens showed greater preferences for P than for PW. One hen (4.2) also showed a greater preference for P than PW when both were paired with W. Hen 4.3 showed greater preference for PW when paired with W than for P when paired with W, that is, for this hen PW was preferred over P. When W was the maintenance diet (Conditions 6 and 7), 4 of the 5 hens (i.e., all except 4.3) that completed Condition 6 showed preferences for W over PW, and 4.3 preferred PW to W. The 2 hens that completed Condition 7 (4.5 and 4.6) preferred W to P in that condition. Both these hens preferred W more when it was paired with PW than when it was paired with P.

When W was paired with PW (Conditions 2, 5 and 6), preference for W was largest for 4 hens when W was the maintenance diet, for 1 hen when P were the maintenance diet, and for 1 hen when PW was the maintenance diet. When W was paired with P (Conditions 3, 4 and 7), preference for W was generally largest when PW was the maintenance diet, except for the 2 hens that completed Condition 7, where preference for W was the largest when W was the maintenance diet. If the data from Condition 8 were included in this analysis, preference for W would have been the largest for 2 of 4 hens when P were the maintenance diet (Condition 8), for 1 hen when W was the maintenance diet, and for 1 hen when PW was the maintenance diet.

Figure 5 shows the log ratios of time spent responding on each key, plotted for the last five sessions of each condition for each hen. The ratio of time spent responding showed similar patterns to the ratio of responses, increasing and decreasing in the same directions for each hen in each condition. Table 3 shows the log q values for time spent responding on each key for Conditions 2-8. The log q values in Table 3 indicate that all hens had the same preferences for each food as shown by the log q values for the responses (Table 2).

Figure 6 shows the log ratios of volume of food consumed by each hen for Conditions 1-8. As the scales sometimes did not register correctly, data from the last five sessions where there were no such problems with the scales were used in analysis, and are given in Appendix A. Except for Condition 1, these values were calculated by subtracting the log ratio of the volume consumed over the last five sessions of a condition from the log ratio of the volume consumed in Condition 1 to correct for any biases from the different magazines. When the value is close to zero, it indicates that the hen consumed approximately the same volume of each food available. When the value is above zero, it indicates that the hen consumed a higher volume of W than the alternative food (PW or P), and when the value is below zero, it indicates that the hen consumed a higher volume of the alternative food than of W. For example, in the last five sessions of Condition 2, Hen 4.5

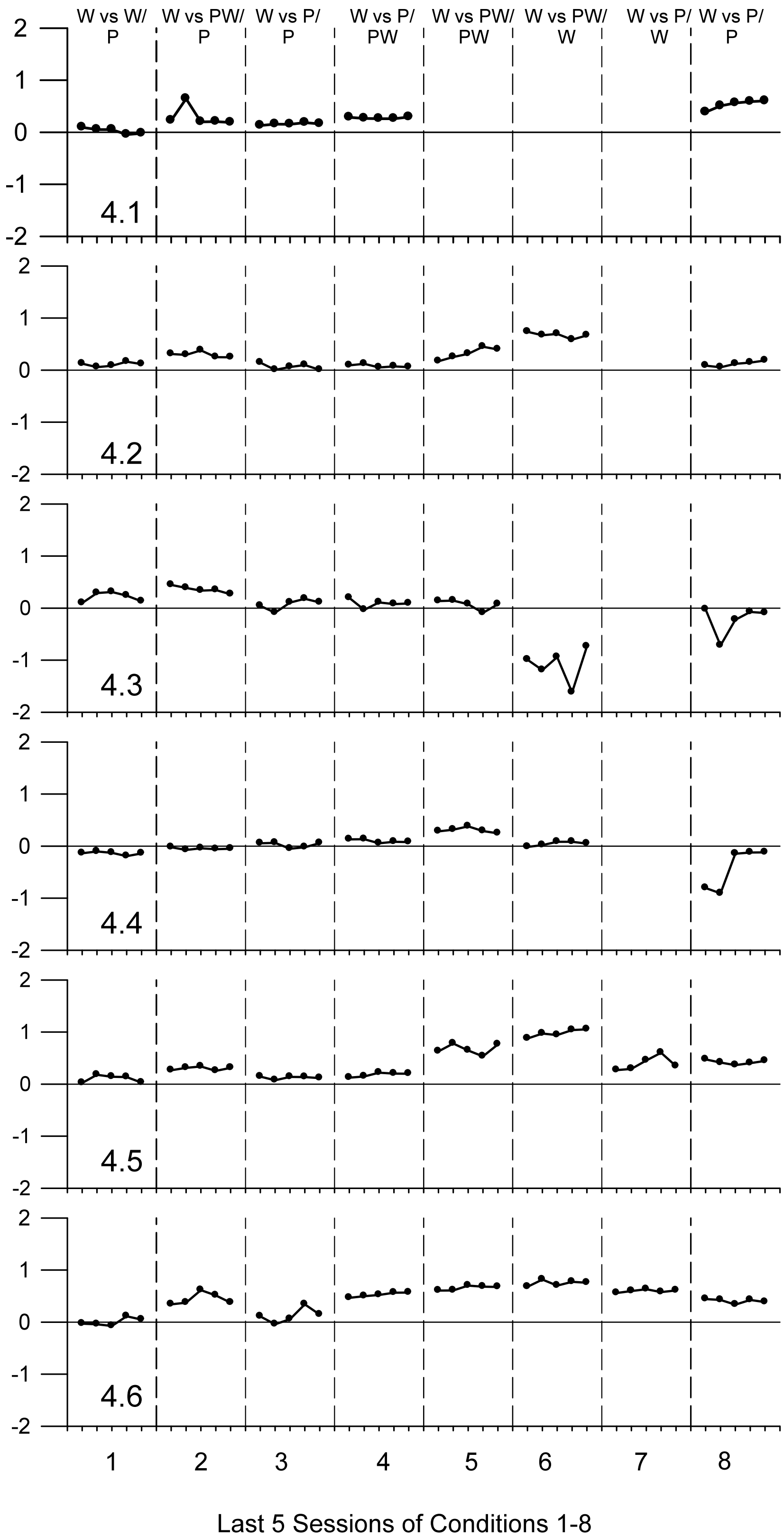

Figure 5. Log ratios of time spent responding on each key plotted for the last five sessions for each hen for Conditions 1-8. Note that W- wheat, PW- puffed wheat and P- pellets.

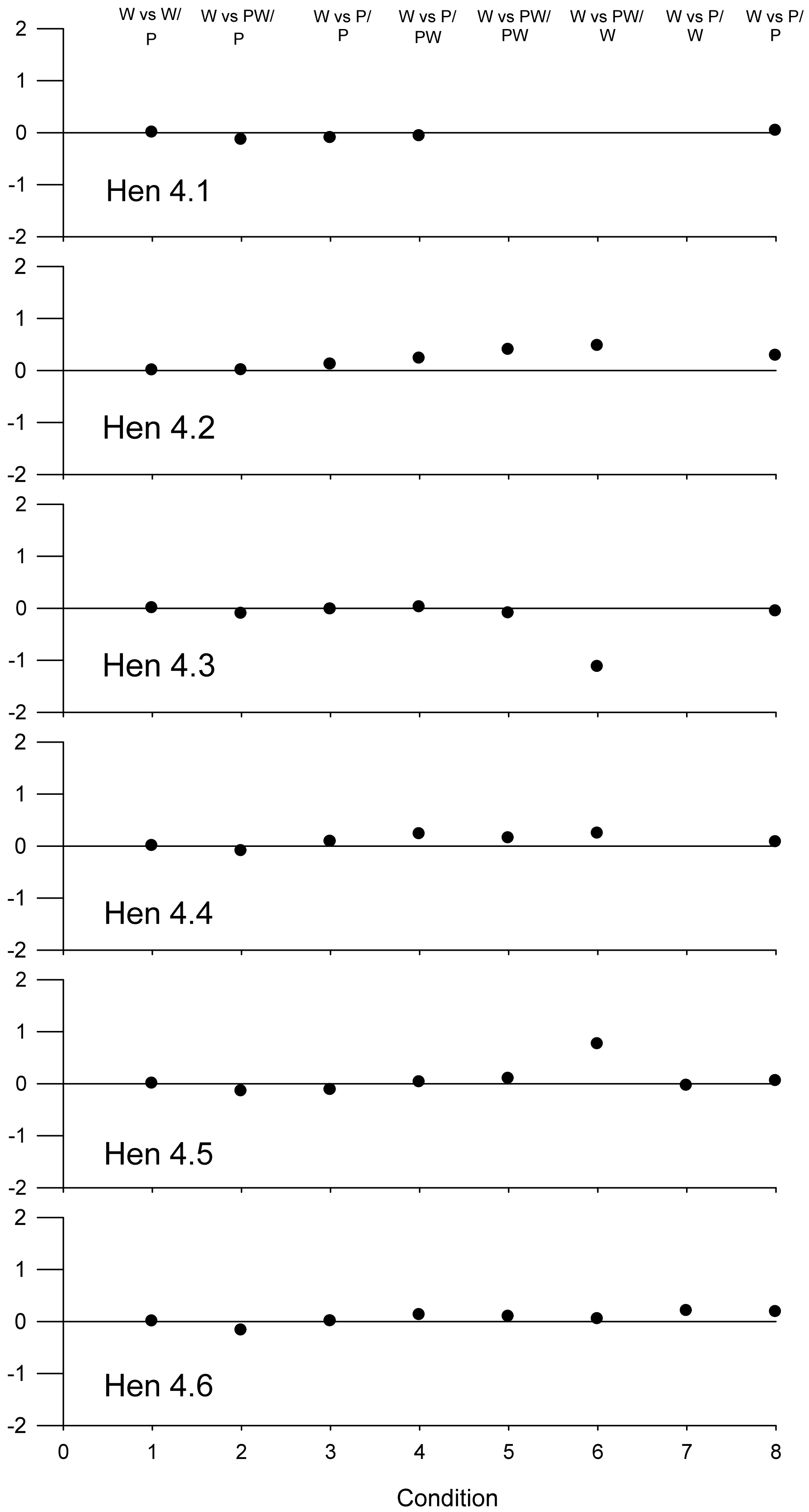

Figure 6. Mean log *q* based on the ratios of the food volumes consumed for the last five sessions of each condition for each hen for Conditions 1-8. Note that W- wheat, PW- puffed wheat, P- pellets.

consumed an average of 1.23 g of W per reinforcer and 0.18 g of PW per reinforcer, but 1.85 cc of W per reinforcer and 1.98 cc of PW per reinforcer. The ratio of volume of food consumed by Hen 4.1 was approximately the same for each condition she completed (Figure 6). Hen 4.2 consumed approximately the same volume of food on each side during Condition 2, and consumed more food on the left side (W) during Conditions 3-6 and 8, with the ratio of food consumed increasing slightly across these conditions but decreasing in Condition 8. In Conditions 5 and 6, the ratio of food consumed by 4.2 reflects her preference for W in these conditions (Figure 2), as she consumed less PW when it was paired with W. Hen 4.3 consumed approximately the same volume of food on each side for Conditions 1-4 and Condition 8, but consumed slightly more on the right side (PW) in Condition 5 when W was paired with PW, and more on the right side (PW) in Condition 6 when W was paired with PW. In Conditions 5 and 6, Hen 4.3 showed larger preferences for PW than W, and these preferences are reflected in the ratio of volume of food consumed in these conditions. Hen 4.4 consumed approximately the same ratio of volume of food in Conditions 2, 3 and 8, and slightly more on the left side (W) in Conditions 4-6, reflecting her slight preference for W in Conditions 4-6. Hen 4.5 consumed approximately the same ratio of volume of food in Conditions 2-5 and Conditions 7 and 8, but consumed more on the left side (W) in Condition 6, reflecting a large preference for W in this condition. Hen 4.6 consumed approximately the same ratio of volume of food in all conditions except slightly more on the right (PW) in Condition 2 and slightly more on the left (W) in Conditions 7 and 8. These data do not reflect her preference for W throughout the experiment, but are all in the same direction as her preference for W, except for Condition 2.

Figure 7 shows the body weights (g) of the hens (left vertical axis) for each of the eight conditions for all 267 days of the experiment; also shown are the weights (g) of post-feed received (right vertical axis) after each session. Note that the scales on the right-hand axes differ across hens to allow all data to be present. For Hens 4.1, 4.3 and 4.4, the grey lines show the estimated weight of post-feed remaining before experimental sessions. Figure 7 indicates that at the end of Condition 4, Hen 4.1 began to lose weight and her body weight dropped to below her target weight range, and her post feed was increased to compensate for this loss. When the hen's body weight was consistently below her weight range and post-feed was not being fully consumed before the next session (in Conditions 5,6 and 7), this hen's maintenance diet was changed back to P for the welfare of the hen and she was removed from further experimental sessions until her weight was consistently within her target weight range again. Hen 4.3 was also consistently below the minimum limit of her target weight range during Condition 7, despite the large amounts of maintenance diet she was fed (between 215 and 365 g). Subsequently, her maintenance diet was changed to P and she was removed from further experimental sessions until her weight was consistently inside her target weight range again. While Hen 4.4 was not consistently below her target weight range, she ceased to consume all the post-feed in her home cage during Condition 8. The amount of food remaining was weighed before experimental sessions. Some of the food missing was eaten and some may have been spilled.

Figure 8 shows the mean log q values based on responding during the COD only, for Conditions 1-8. They were calculated by subtracting the log ratio of within-COD pecks in Conditions 2-8 from the log ratios of within-COD pecks in Condition 1. Figure 8 indicates that all of the hens showed very little preference for any food while the COD was in effect. Figure 9 shows the mean log q values

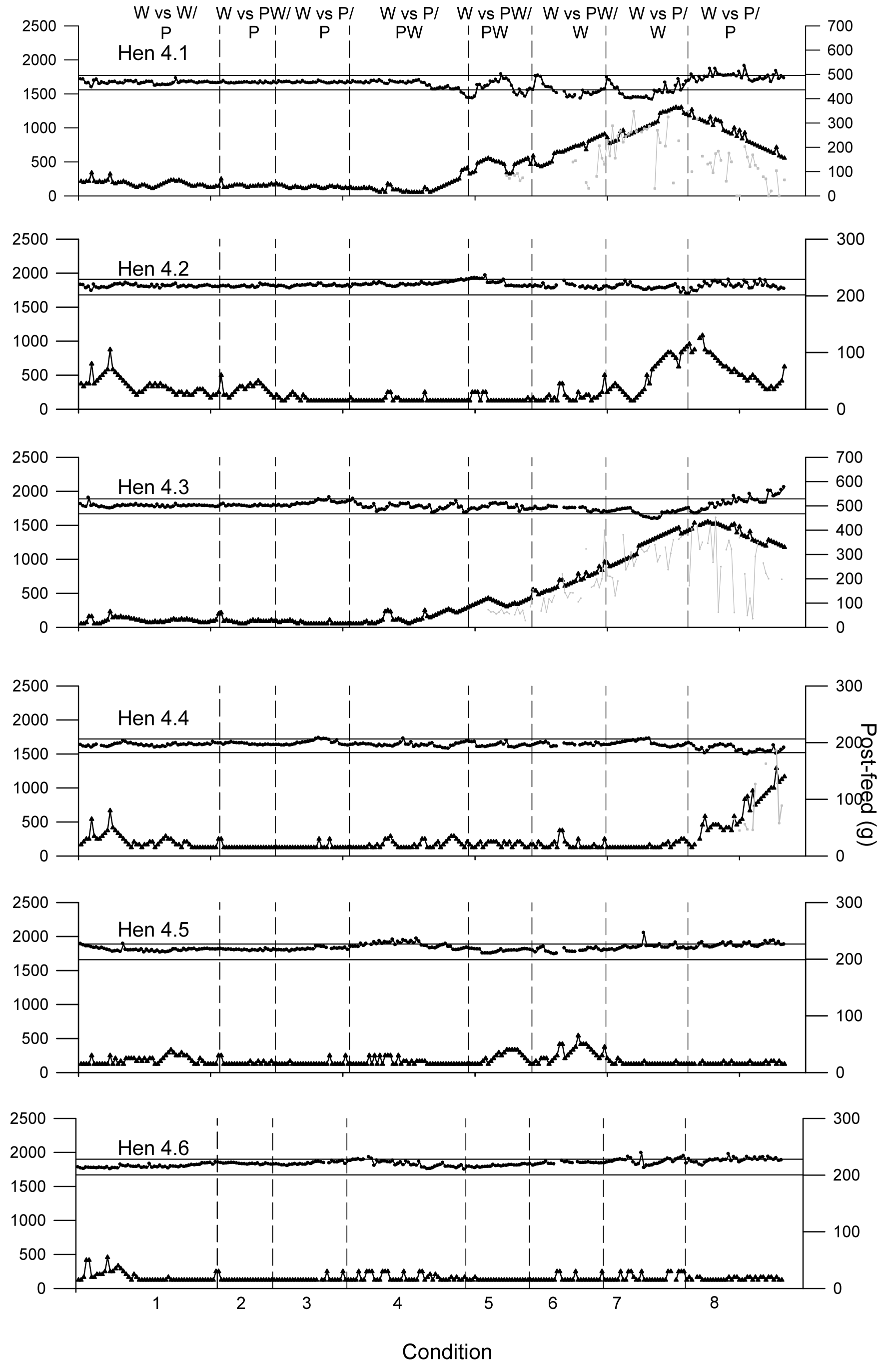

Figure 7. Body weights of hens (g) (left-hand axes) and weights of post-feed (g) (right-hand axes) for every day of the 267 days of the experimental conditions. The horizontal lines indicate the maximum and minimum parameters of each hen's target body weight, and the grey lines indicate the weight of post-feed remaining in the hens' food containers before experimental sessions. Note the scales on the right-hand axes differ across hens, W- wheat, PW- puffed wheat and P- pellets.

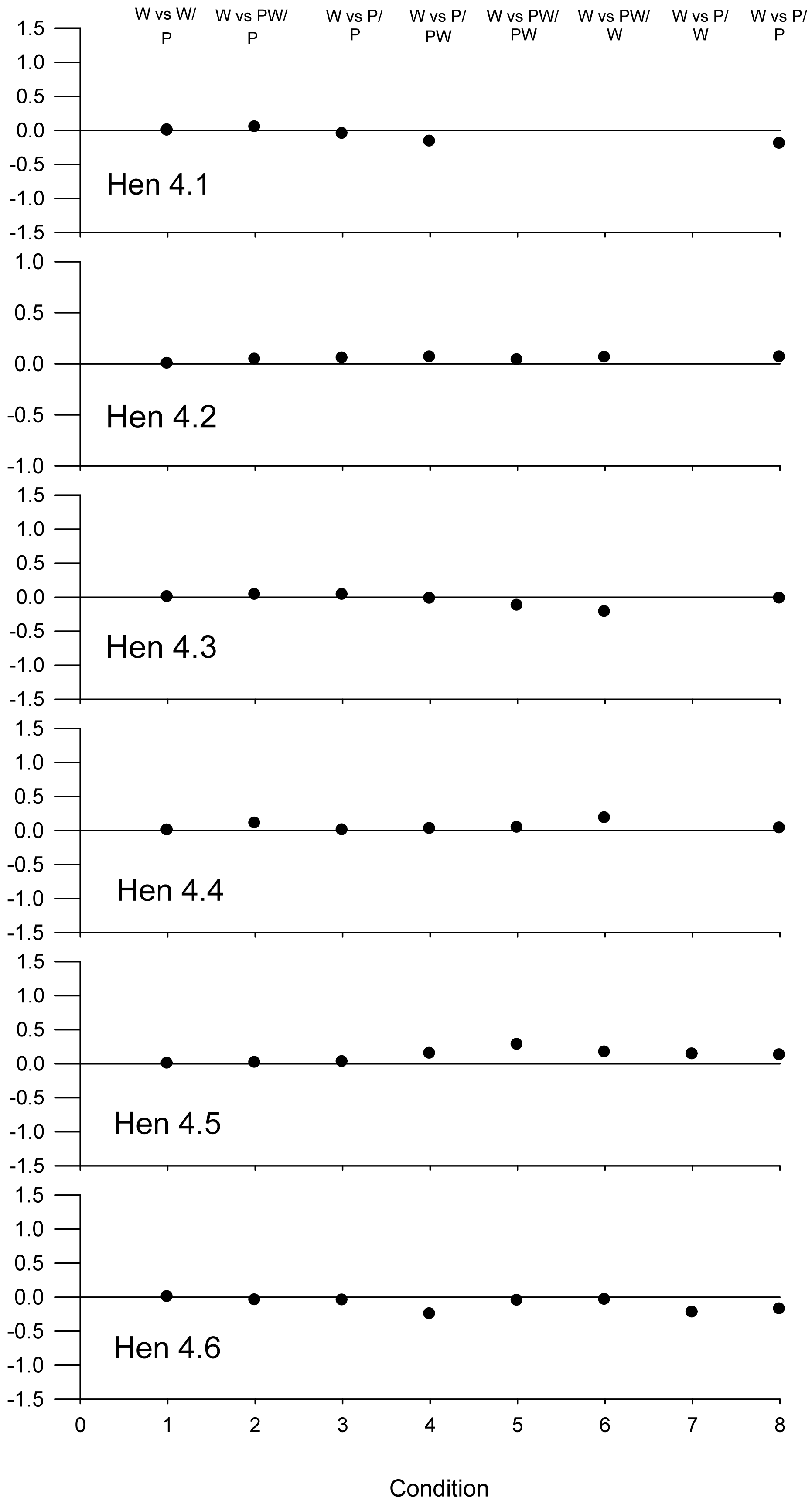

Figure 8. Mean log *q* values of within-COD pecks for each hen for Conditions 1-8. Note that W- wheat, PW- puffed wheat and P- pellets.

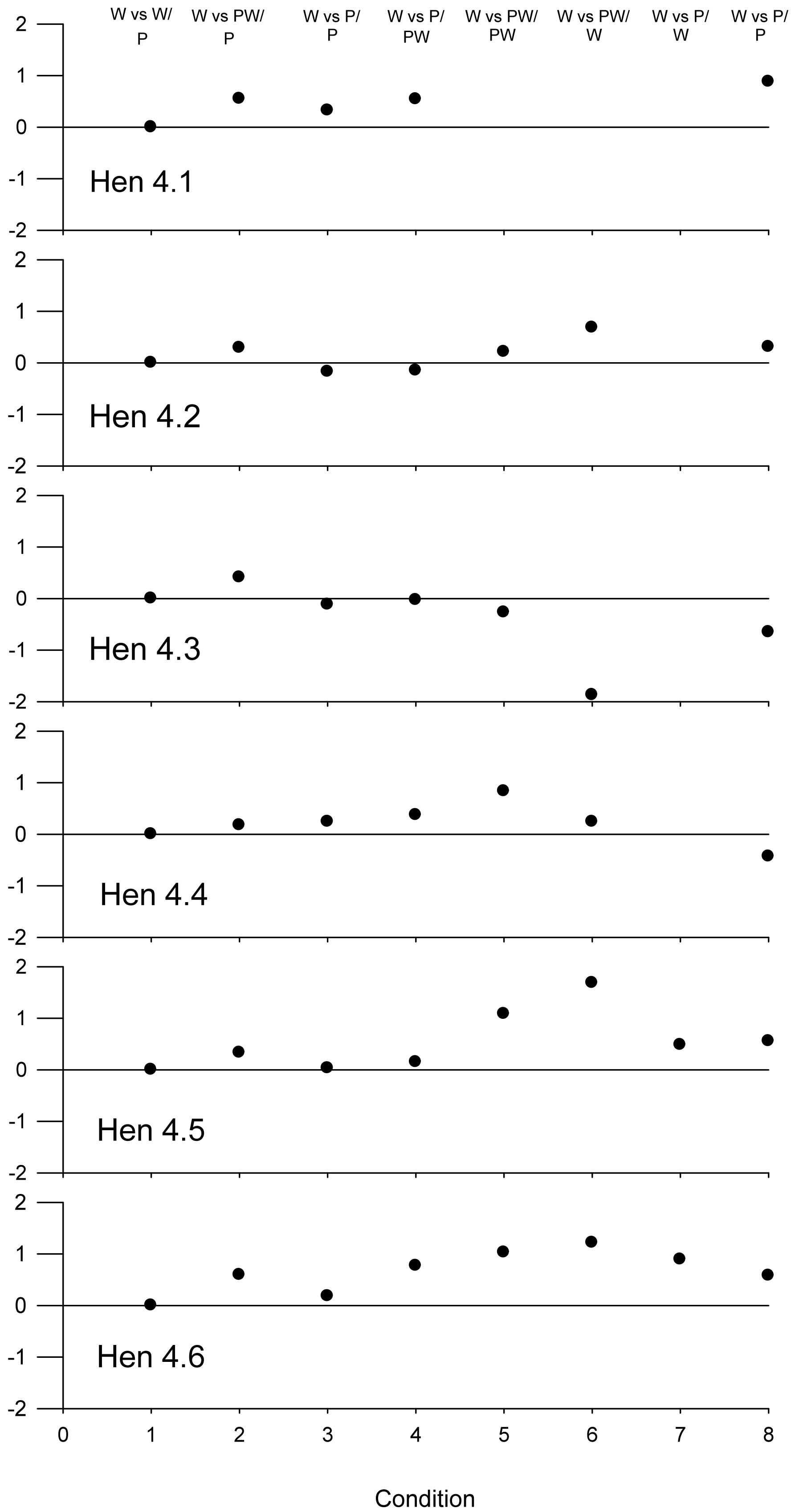

Figure 9. Mean log *q* values of post-COD pecks for each hen for Conditions 1-8.

Note that W- wheat, PW- puffed wheat, P- pellets.

for the ratios of post-COD pecks for Conditions 1-8, calculated as for the within-COD pecks. The values in Figure 9 show the same patterns of preferences as in Figure 2, indicating that the biases in responding occurred after the COD had ended.

Figures 10-17 (Appendix B) show the frequency of responses of each hen on the left and right keys for each four-minute interval of the last five sessions of each condition. These data show a range of patterns across sessions over all conditions and all subjects. There were no consistent changes in responding across maintenance diets or the same pairs of food types across the sessions.

Discussion

This study examined whether altering the maintenance diets of hens affected their preferences for different types of food (W vs P and W vs PW) under concurrent schedules of reinforcement. Hens responded in experimental sessions on VI 60-s VI 60-s dependent concurrent schedules of reinforcement with a 2-s COD for W on the left key, and either P or PW on the right key. They were fed a minimum of 15-g post-feed as their maintenance diet food (either W, P or PW) after each experimental session. The results supported the hypothesis that the maintenance diet of hens affects their preferences for different food types. Preferences were, however, idiosyncratic across hens and so were the changes in preferences.

In summary, for the response data when P were the maintenance diet, all hens preferred W to PW, 2 hens preferred P to W, and 4 hens preferred W to P, but all showed weaker preferences for W compared to P than compared to PW. When the maintenance diet was changed to PW, 4 hens showed greater preferences for W than P, while 2 hens showed greater preferences for P than W. Four hens showed greater preferences for W than PW, and these preferences were stronger for W than when W was paired with P. One hen showed a greater preference for PW than W, a stronger preference for PW when paired with W than for P when paired with W. Hen 4.1 did not complete Condition 5. When the maintenance diet was changed to W, 4 hens showed greater preferences for W than PW, 1 hen showed a greater preference for PW than W, and 4.1 did not complete Condition 6. Two hens showed greater preferences for W than P, but weaker preferences for W when it was paired with P than with PW. Hens 4.1-4.4 did not complete Condition 7.

When W was paired with PW, 3 hens showed the greatest preference for W when W was the maintenance diet, 1 hen showed the greatest preference for W when P were the maintenance diet, and 1 hen showed the greatest preference for W when PW was the maintenance diet. Note that Hen 4.1 did not complete the necessary conditions (Conditions 5 and 6) for this comparison to be made. When W was paired with P, 4 hens showed the greatest preference for W when PW was the maintenance diet, and 2 hens showed the greatest preference for W when W was the maintenance diet. Hens 4.1-4.4 did not complete Condition 7 (W vs P/W), thus the results are inconclusive for these hens. Data from Condition 7 suggest that Hens 4.2 and 4.3 may have shown strong preferences for P in this condition and subsequently may have had the greatest preference for P when W was the maintenance diet. The data also suggest that Hen 4.4 would have shown similar preferences for W vs P as in Conditions 3 and 4. Hen 4.1 did not produce enough data in this condition to predict any results. When W was paired with P, there were few changes in the hens' preferences when the maintenance diet was altered. When W was paired with PW, there were large changes in the hens' preferences when the maintenance diet was altered.

Although there were different changes in preferences across animals, the preferences for each hen were reliable. The hens that preferred W tended to prefer it in most conditions, and the hen that preferred either P or PW to W tended to prefer those foods in that order across conditions. This is consistent with the findings of Cronin (2012), that possums had idiosyncratic preferences for different food types, but those preferences were stable across different preference assessment procedures.

The results of this study are consistent with those found by Foster et al. (2009), that when hens are fed a maintenance diet of P, W is preferred more than

PW. This was found for all hens in the present study. Jackson (2011) also found that after being maintained on a diet of P, 3 of 6 hens preferred W to PW and P. Jackson (2011) also found that 1 hen preferred P to W and PW, and 2 hens showed no preferences. The results of the present study are similar, in that 4 hens preferred W to PW and P, and 2 hens preferred P to W and PW.

The results of the present study show that when P were available (Conditions 3, 4 and 7), P were most highly preferred by all hens when P were the maintenance diet. Thus being exposed to P seemed to increase their preference for it. These results are inconsistent with previous research with humans showing that deprivation of a stimulus increases responding for that stimulus and satiation of a stimulus decreases responding for that stimulus (Gottschalk et al., 2000). Gottschalk et al. (2000) investigated the food preferences of 4 individuals under three conditions: Satiation, deprivation and control. The authors found that in the satiation condition, responding decreased for the food type that the participant had been given free-access to in the 10-min prior to assessment. They also found that in the deprivation condition, responding increased for the food type the participant had had no access to in the 48-hr prior to the assessment. Therefore, it may have been expected that when P were the maintenance diet, preference would be higher for a food that the hen had been deprived of, i.e., not the maintenance diet food. It is important to note, however, that only 2 hens completed Condition 7, but the data suggest that the other 3 hens that responded in this condition may have shown greater preferences for P than W in this condition. This would suggest that greater preferences would have been found for P when W was the maintenance diet, a result that would have been consistent with the research carried out by Gottschalk et al. (2000).

When PW was available (Conditions 2, 5 and 6), preference for PW was found to be the greatest for 3 of 5 hens when P were the maintenance diet, for 1 hen when W was the maintenance diet, and for 1 hen when PW was the maintenance diet. These results for 4 of 5 hens are consistent with the research carried out by Gottschalk et al. (2000), who found that access to a stimulus before a session led to decreased responding for that stimulus. The research carried out by Gottschalk et al. differed from the present experiment in that their participants were humans not hens, and their satiation condition involved participants being allowed free access to the stimulus for the 10-min period prior to the experimental sessions, but in the present study, hens were not allowed free access to the maintenance diet foods. Also, during the deprivation condition, Gottschalk et al.'s participants were not allowed access to the stimuli for 48-hours before the experimental sessions, but in the present study the hens had been fed approximately 24-hours prior to each experimental session. These factors may account for the different outcomes in the present study. It is interesting to note, however, that when Hens 4.1 and 4.3 were being fed more of the maintenance diet food than they consumed before the next experimental session, this was the equivalent to being free-fed that food, and these hens ceased to respond for the same food type as their maintenance diet food. This is similar to the results from the satiation conditions in the research reported by Gottschalk et al. (2000). Further research could be carried out using subjects who were at 100% of their free-feeding body weights for satiation conditions, and hens that were deprived of a food for 48-hours prior to experimental sessions to determine the effects of satiation and deprivation on the food preferences of hens.

When W was available (Conditions 1-7), preference for W was the greatest for Hen 4.1 (that only completed Conditions 1-4) and Hen 4.3 when P were the maintenance diet, for Hens 4.2, 4.5 and 4.6 when W was the maintenance diet, and for Hen 4.4 when PW was the maintenance diet. Half of the hens still showed greater preferences for W when W was the maintenance diet, suggesting that, consistent with previous findings that food deprivation may not affect hens' motivation to work for food if that food is highly reinforcing (Bruce et al., 2003), W may be a highly preferred reinforcer for these hens.

Previous research has found that providing free access to a reinforcer before experimental sessions can decrease an animal's motivation to work for that reinforcer (Podlesnik & Shahan, 2009), and results from the present study are consistent with this finding. Specifically, when hens were given more of the maintenance diet than they consumed before the next experimental session (Hens 4.1 and 4.3), responding for that food decreased. This may have presented a confound in the present experiment, as preferences for the different food types may have been different had these hens not been fed such large amounts of maintenance diet food. Future research could be conducted to determine what quantities of post-feed provided as a maintenance diet would affect preferences for different food types. Future studies could also examine the food preferences of hens when the quantity of maintenance diet food is kept the same.

Within-COD and post-COD data were analysed, and it was found that the biases in responding occurred after the COD period had ended. This finding is consistent with research carried out by Temple et al. (1995), which showed that the hens displayed little sensitivity during the COD period to the reinforcement schedules in effect. McAdie et al. (1996) also found little sensitivity during the COD period when hens were responding with an aversive noise overlaid in the experimental chamber, indicating that the post-COD data were likely to be a more sensitive measure of noise bias that total response data. The data in the present study are consistent with these studies, but are the first data found to show that bias for food types, and subsequently food preferences, occurs after the COD period. Future research could investigate whether or not changing the length of the COD would affect sensitivity during and after the COD periods when hens are responding for different food types.

The values of the inherent bias in the present study ranged from -0.08 to 0.19, a wider range than the inherent biases found for the hens in the study carried out by Foster et al. (2009), which ranged from -0.21 to -0.03. The inherent biases in the present study included some biases towards the left and some towards the right, whereas in Foster et al.'s study, all biases were towards the right key. The log q biases in Foster et al.'s study, however, were all towards the left key (wheat) when compared to both puffed wheat and honey-puffed wheat. The size of the biases for W compared with PW ranged from 0.34-0.92, whereas in the present study the biases for W compared with PW (with a P maintenance diet) were generally smaller, and ranged from 0.14 to 0.39. The direction of the biases were the same for both studies when P were the maintenance diet, but in the present study when the maintenance diet was changed, log q values ranged from -0.21 to 0.75 when PW was the maintenance diet and from -1.05 to 1.23 when W was the maintenance diet, showing the change in preferences between W and PW when the maintenance diet was changed.

Matthews and Temple (1979) suggested that dependent concurrent schedules may yield preference measures that underestimate animal's actual preferences. This is because when dependent concurrent schedules are in effect, the reinforcers on both sides of the schedule must be earned. Matthews and Temple (1979) found that cows still responded on both sides of the concurrent schedules, even though one option was an empty bucket, resulting in possible underestimation of the cows' preferences for hay and dairy meal. This may have occurred in the present study, as dependent schedules were used. From Condition 6 onwards, some hens ceased to respond on one of the concurrent schedules. Due to the dependent nature of the schedules in this experiment, experimental sessions ended before all the reinforcers available were earned. This reduced the food available in the experimental session, and some hens lost weight so had to be fed large amounts of the maintenance diet food in their home cages. When the hens were receiving more of the maintenance diet than they consumed before the next experimental session, these hens ceased responding on the side of the concurrent schedule that would result in that food as a reinforcer. Hens 4.1 and 4.3 ceased responding during Condition 6, and Figure 5 indicates that Hen 4.5 also stopped consuming reinforcers on the right side of the concurrent schedule during Condition 6. Future studies could use independent concurrent schedules of reinforcement, after an initial forced choice for the subject to sample both foods available, to determine whether or not independent schedules would lead to more hens completing all the conditions than in the present study.

Even though the number of reinforcers was equal for each completed experimental session, the ratio of volume of food consumed differed for different hens in different conditions. In most cases, preferences were accompanied by proportionate increases of the volume consumed of the preferred food. No research could be found on the proportions of volume of food consumed in concurrent schedules, so further research in needed to investigate this occurrence. The data in the present experiment suggest that the hens' eating behaviours changed, and while they may have earned all the reinforcers available, they either consumed more from the magazine containing the preferred food, or less from the magazine containing the non-preferred food.

Within-session data show a range of patterns across sessions over all conditions and all subjects, with no consistent changes in responding across maintenance diets or the same pairs of food types across the sessions. The rate of responding changed within the experimental sessions, but did not change consistently. This finding is inconsistent with the research carried out by Murphy, McSweeney, and Kowal (2003) who found that the rate of responding for both rats and pigeons changed systematically within sessions when both types of animals were responding for qualitatively different reinforcers on concurrent schedules. Murphy et al. (2003) also found that pre-feeding either 1 or 4 hours before experimental sessions led to decreased responding within sessions, but pre-feeding 12 hours before experimental sessions had no effect on within-session responding. In the present study, supplementary feeding occurred at least 12 hours prior to experimental sessions, which could explain why there were no consistent effects of changes of maintenance diet on within-session responding in the present study.

In the present experiment it was necessary to control body weight because it has previously been shown to act as an establishing operation that changes the value of food for animals in subsequent experimental sessions (Ferguson & Paule, 1997). Throughout the present experiment, several hens did not complete all the conditions when they were outside their target weight range. This meant that comparisons could not be made for these hens across all conditions. Future studies could examine the food preferences of hens maintained at different body weights to determine the effects of body weight as an establishing operation for food preferences, and more data may be able to be collected (and more comparisons able to be made) than in the present study.

Food restriction has been found to be another establishing operation that can affect an animal's motivation for food (Bokkers et al., 2004). In the present study, the amount of post-feed the hens were given after experimental sessions varied considerably, from 15-400 g. While altering the amount of food given as the maintenance diet was necessary to maintain the hens in their target weight range, it is possible that control over the independent variable was lost in this study, possibly affecting the preference measures found. That is, although body weight was kept within range, the amount of maintenance diet food provided after experimental sessions varied greatly. It is possible also that being fed 15 g of maintenance diet may not have been a large enough amount of food to have an effect on the preferences of the hens in this study. The hens that received over 300 g of maintenance diet food showed distinct changes in patterns of responding, changes which were not shown by hens who regularly received only 15-20 g of maintenance diet food.

There may have been effects of the order of conditions in the present study. In Condition 8, hens responded for the same foods as in Condition 3 (W vs P), with the same maintenance diet (P), yet the results showed slightly increased ratios of responding for 5 hens' preferred foods, and increased ratios of responding in the opposite direction for Hen 4.4, in Condition 8 compared to Condition 3 (Figure 2). Data were also variable for Hen 4.2, and while this hen's responding was initially trending towards the same ratio of responding as her responding in Condition 3, data from the last four days she completed of Condition 8 showed strong preferences in the opposite direction to those in Condition 3. Data may have been variable for Hens 4.2 and 4.4 due to these hens ceasing to earn and consume all reinforcers, resulting in longer sessions and instability in behaviour. The differences in the results of these two conditions suggest that the order of exposure to the different maintenance diet foods may have affected the strength of preferences in this study. Further replication of some conditions may be necessary to determine the exact effects of the order of the experimental conditions.

Future studies could implement a closed economy system, where the food earned during experimental sessions is the only food the subject receives. While this would not address the effects of altering maintenance diet on preference for different food types, complications resulting from varying quantities of post-feed may be reduced. However, such studies are likely to have large variations in body weight. Thus studies of the effects of body weight are also needed.

As discussed earlier, many different methods are used to assess preferences, each method having benefits and limitations. It is possible that using different methods of preference assessment may yield different measures of preference than those found in the present study when preference was assessed with different maintenance diets. Not accounting for idiosyncratic preferences, one may speculate that in a free-access preference assessment, hens would consume less of the food that was used for their maintenance diet compared to other foods available, yet free-access preference assessments with hens may not always result in distinguishable measures of preference between foods (Jackson, 2011). In a SS preference assessment, it may be expected that hens would consume very little (or none at all) of the food used for the maintenance diet, as occurred in the present study when some hens ceased to consume W when it was used as the maintenance diet food. In a PS preference assessment, it may be expected that the food used as the maintenance diet food would be chosen less frequently than the alternate food. In a MSWO preference assessment, one may speculate that the maintenance diet food would be selected least often by the hens, potentially yielding similar results to a PS preference assessment (Cronin, 2012). In a MSW preference assessment, it may be expected that the maintenance diet food would be selected infrequently, if at all. Future research could implement different methods of preference assessment to determine whether they yield similar or different results to those found in the present study.

A review of literature revealed only two studies investigating different types of maintenance diets and their effects on responding in experimental sessions (Elia, Erb & Houpt, 2010; Jackson, 2011). Elia et al. (2010) investigated the effects of altering the maintenance diets of horses on their demand for different foods, and found that altering the maintenance diets did affect demand for the different foods, but they did not investigate the horses' preferences between the food types used. The present study shows that for commonly used laboratory animals, maintenance diet may present a confound in experiments that changes the relative value of reinforcers, that may affect motivation to work for them. One may speculate that using specific maintenance diet foods could lead to overmatching or undermatching in experiments using concurrent VI schedules, and could contribute to peculiar findings when reinforcer magnitude is varied (e.g., see Bonem & Crossman, 1988 for a review on reinforcer magnitude effects).

In conclusion, altering the maintenance diet of hens affected their preferences for the different food types (W, P and PW) when used as reinforcers. Hens generally preferred W to either PW or P in all conditions, but the strength of these preferences changed when the maintenance diet was changed. When W was compared to PW, preference for W was generally the highest when W was the maintenance diet, and when W was compared to P, preference for W was generally highest when PW was the maintenance diet. Due to hens being outside their target weight ranges, several conditions were not completed by all hens and some comparisons could not be made. The hens' preferences in this study may have been affected by factors other than the type of maintenance diet food used, however, such as the quantity of maintenance diet food provided after experimental sessions, and differing levels of deprivation and satiation before experimental sessions. The present experiment leads the way for future research investigating the food preferences of hens, but in relation to variables such as body weight, quantity of maintenance diet food, type of economy in effect, quantity of reinforcers consumed, and type of concurrent schedules used.

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