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How tufted capuchin monkeys (Cebus apella) rank monkey chow in relation to other foods

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Abstract

*Captive primates are usually fed on monkey chow, a high-energy food designed to provide a complete and balanced diet for primates. In addition to the nutritional value of a food, its palatability, frequency of presentation in the daily diet and sensory stimulation may also be important for determining whether it is accepted by the animals. The aim of this study was to evaluate the food preferences of 26 captive capuchin monkeys (*Cebus apella*) using monkey chow and a variety of foods, which ranged from being very familiar to completely novel to the monkeys, and to assess whether the frequency of presentation in the daily diet and sensory stimulation affected their food preferences. Food preferences were scored in terms of the food item chosen and whether it was then eaten. In Experiment 1, subjects encountered paired combinations of seven familiar foods (present in the monkeys' diet with different frequencies), including monkey chow. In Experiments 2 and 3, monkey chow was paired with seven novel foods (not previously present in the monkeys' diet) and seven ex-novel foods (previously only encountered repeatedly during an earlier experiment) respectively. The results show that monkey chow, despite its high energy content, was not very attractive to capuchin monkeys. Other familiar foods (especially those not presented daily) were chosen and eaten more frequently than the monkey chow, and novel foods were chosen more frequently than the monkey chow. The findings of this study have implications for the feeding husbandry of captive primates. Familiar foods presented in the diet each day are less preferred; therefore good practice would be to alternate foods over time. Occasional presentation of novel food items could be a stimulating and economical method of providing sensory enrichment.*

Keywords: *animal welfare*, Cebus apella, *dietary husbandry, food preferences, monkey chow*

Introduction

Proper nutrition and dietary husbandry are fundamental for the health and well-being of captive non-human primates. Nutritional deficiencies can produce specific symptoms, and there is a well-established relationship between nutritional status and susceptibility to infectious diseases (Ullrey 1993). Because captive primates do not consistently choose a complete diet when presented with a selection of cultivated foods (Ullrey 1989; Oftedal & Allen 1996), the daily use of a nutritionally balanced dry food is recommended as the predominant item in captive primates' diet (BANR 2003). These foods are specifically designed to provide the necessary nutrients for growth and reproduction and to prevent nutritional deficiencies. Furthermore, these dry foods are easy to handle, store and administer to the animals. Consequently, manufactured diets (eg monkey chow) are widely used in the captive environment.

Although monkey chow fulfils the nutritional requirements of captive primates, they do not seem eager to eat it, suggesting that their needs are not completely satisfied by this diet. Other factors, such as palatability, diet variety and sensory stimulation, also play an important role in food acceptance. Palatability — the pleasantness of taste — can be thought of as the sensory capacity to stimulate ingestion of a food. This definition takes into account that palatability is jointly determined by the nature of the food (eg smell, taste and texture), the sensory capability and the metabolic state of the subject (Blundell & Stubbs 1999).

The frequency of presentation of a food item in the diet can also affect food preference. Sensory-specific satiety seems to be independent from caloric content and nutrient composition (Rolls 1990). Also, it has been shown in rat pups that the frequent exposure to a flavoured diet can lead to a decrease in oral responsiveness (Swithers-Mulvey & Hall 1992). The rapidity of changes in hedonic rating suggests that it is related to a difference in the food's sensory attributes rather than to its post-ingestive feedback (Balleine & Dickinson 1998).

Finally, feeding also provides sensory stimulation, promoting the well-being of captive primates by environmental enrichment. Wild primates acquire nutrients by spending between 25% and 90% of their waking hours foraging (Clutton-Brock & Harvey 1977), and food selection relies on perceiving a variety of visual, olfactory and gustatory stimuli that, once processed, require decision making. In contrast, captive primates usually feed

Table 1 Energy content (kcal) of the foods used in the three experiments and percentage of energy compared with monkey chow. Energy content of each food is for a 100 g edible portion (data from INRAN's on-line database 2000; Souci *et al* 1999; Matthews *et al* 1987).

Familiar foods			Novel foods			Ex-novel foods		
	Energy (kcal)	% kcal chow		Energy (kcal)	% kcal chow		Energy (kcal)	% kcal chow
Chow	280	100.00	Chow	280	100.00	Chow	280	100.00
Tangerine	72	25.71	Blueberry	57	20.36	Pineapple	40	14.29
Banana	65	23.21	Shrimp	120	42.86	Canned meat	141	50.36
Potato	85	30.36	Palm pith	28	10.00	Pasta	137	48.93
Pear	35	12.50	Artichoke	45	16.07	Tomato	19	6.79
Bread	182	65.00	Lychee	66	23.57	Grapefruit	26	9.29
Lettuce	19	6.79	Lemon	20	7.14	String bean	25	8.93
			Soy sprout	122	43.57	Savoy cabbage	19	6.79

on monkey chow that quickly fulfils their nutrient and energy requirements.

The aims of this study were to experimentally evaluate the extent to which monkey chow was preferred when compared with foods that ranged from being very familiar to completely novel to the monkeys, and to assess whether an individual's food preference was influenced by other factors, such as frequency of presentation in the diet and sensory stimulation provided by a novelty effect. In Experiment 1, capuchin monkeys were presented with paired combinations of seven familiar foods, including monkey chow, to assess their preferences towards them. Because these foods were already present in the monkeys' diet, with different frequencies (some every day, others more rarely), we aimed to assess whether familiarity affected their preference towards them. In Experiment 2, we investigated the response of capuchins towards seven novel foods, never encountered before, when paired with monkey chow. Finally, in Experiment 3, monkeys were presented with monkey chow paired with seven ex-novel foods — foods previously encountered only during a previous study (for details see Visalberghi *et al* 2003b).

Capuchin monkeys (*Cebus apella*) are particularly suited to this study as their diet is extremely adaptable (Fragaszy *et al* 1990, 2004; Kinzey 1997). They feed on a wide variety of food items, but mainly plant matter, especially fruits, and a variety of invertebrates and other animal matter. To adapt to seasonal changes in food availability, capuchins exploit the food sources available in different environments (Terborgh 1983; Brown & Zunino 1990; Perry & Rose 1994; Kinzey 1997; Sussman 2000; for a review see Fragaszy *et al* 2004). Consequently, they often have to deal with novel foods, and to learn what to feed upon (Visalberghi & Addessi 2003). However, wild, and to a lesser extent captive, capuchin monkeys are neophobic towards novel food items (Visalberghi & Addessi 2003; Visalberghi *et al* 2003a). When first encountering novel foods they are cautious and typically ingest very little, but the presence of group members and repeated exposure facilitates the acceptance of novel foods (Visalberghi *et al* 1998; Visalberghi & Addessi 2000, 2003). Nevertheless, from the very first encounter, novel foods elicit interest. A group member holding a novel food, or a familiar food with a novel odour, attracts more interest from group members than when the food is familiar (Visalberghi & Fragaszy 1995; Drapier *et al* 2003). We expected, given the capuchins' interest in novelty, that despite their reluctance to ingest new foods they would be motivated to explore them. In order to distinguish between interest, exploration and actual consumption of a food, we assessed preferences both in terms of the food item chosen (the most widely used and easily scored measure) and whether the food item was eaten — undoubtedly the most representative measure of how much a food is liked.

Materials and methods

Animals

Twenty-six capuchins were used in all three experiments: 10 males and 16 females. Five were juveniles (< 4 years old), and 21 were adults (> 4 years old). The range was 2–35 years, with an average age of 13 years. The subjects lived in four groups, housed in indoor–outdoor cages, and group size ranged from 3 to 12 animals. The area for each group ranged from 90 m^3 to 135 m^3, according to group size. Cages were furnished with perches and slides, and various plastic toys and wooden blocks were provided on a daily basis. All cages were connected by sliding doors. Every afternoon, monkeys received monkey chow, fresh fruits and vegetables. Three times per week monkeys received a mixture of curd cheese, vitamins, egg, bran, oats and sugar.

Apparatus

In all three experiments, two different food items were positioned on a rectangular Plexiglas™ tray (27 × 40 cm, width × length). The tray was divided in half by a Plexiglas™ divider placed perpendicular to the tray (27 × 1 × 9 cm, width × depth × height). The tray had a plastic handle on each side, which allowed it to be moved easily. The tray included a 0.5 cm deep hollow (1.5 cm diameter) on both sides of the divider. The two hollows were 15 cm from one another, and during each experiment

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one food item was positioned in each hollow. All food items were presented to the subjects in pieces of similar sizes.

Experiment 1 Chow versus familiar food

Foods

In Experiment 1, seven different familiar foods were used: tangerine, banana, pear, lettuce — all of which were fresh — boiled potato, bread and monkey chow (Altromin-A pellets, Rieper standard diet for primates: A Rieper SpA, Molino/Industria Mangimi, Vandoies, BZ) (see Table 1 for the energy content of the foods). According to the frequency with which the animals received these familiar foods during the year, the foods were subdivided into two groups: 'everyday' foods (monkey chow, bread and lettuce given every day, all year round), and 'not-everyday' foods (potato and banana given twice per week, all year round; tangerine and pear given every day, but only during autumn and winter).

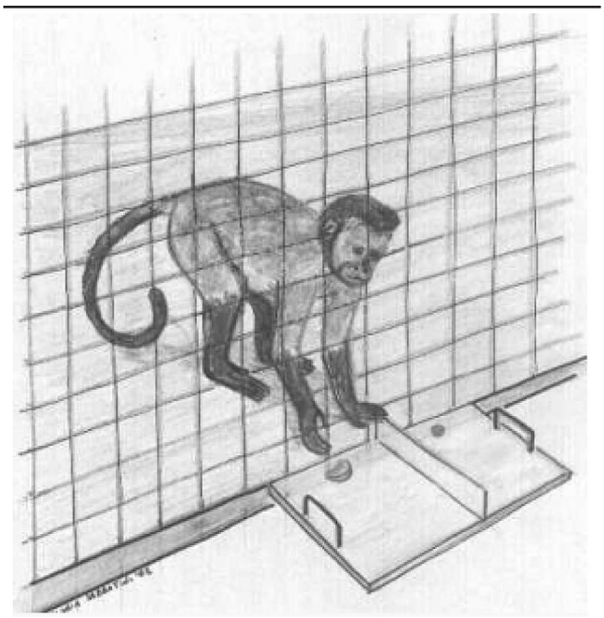
Procedure

In Experiment 1, each capuchin monkey was presented with all possible binary combinations between all the seven familiar foods. This procedure was repeated three times in order to produce sufficient data to determine the relationship between preference and food availability — the extent to which the food is available in the diet. Therefore, there was a total of 63 binary choices for each of the 26 subjects (1638 trials).

Each trial was carried out on an animal while individually housed in the 'indoor' section of the cage (see 'Animals' section). Testing of the subject while in the social group would have led to the introduction of further variables, such as social rank and competition, on food preference. There is also evidence that the presence of group members facilitates the acceptance of novel foods in captive capuchin monkeys (Visalberghi & Addessi 2000, 2003). The capuchins used in this study were accustomed to being tested in isolation and were not distressed when separated from group members for short periods of time. The animals also remained in olfactory and auditory contact with their group mates, present in the outdoor section of the cage.

During each trial, the apparatus was presented to the subject by an experimenter: G Sabbatini or M Stammati. The apparatus contained one familiar food on one side and another familiar food, or monkey chow, on the other (positions of the food were counterbalanced across trials). The experimenter approached the testing cage holding the apparatus and presented it to the experimental subject, which could reach for the food by putting its hands though the wire-mesh (Figure 1). As soon as the subject chose one food, the apparatus was immediately retrieved. If the subject left the food on the tray, without choosing either of the two pieces, the experimenter waited for 3 min and then moved on to the next trial. In each trial, the food item chosen by the subject, and whether it was eaten (scored when the subject ate more than half of it) or not eaten (scored when the food was chosen and discarded, or chosen, tasted and discarded; in this case the subject ate less than half of the food) was scored. Testing occurred between 1100h and 1500h, before groups received their main daily food ration, at around 1600h.

Figure 1



Experimental procedure: the subject, in the indoor section of its cage, puts its hands through the wire mesh and chooses between two foods placed on each side of the experimental apparatus. Drawing by G Sabbatini.

Statistical analysis

Food preferences were analysed using the scores for both food items chosen and food items eaten. When the assumptions of parametric statistics were not met, non-parametric tests were used.

The whole data set was analysed using a one-way ANOVA to assess the monkeys' preferences towards the familiar foods (a total of 1638 trials; see 'Procedure' section). For *post hoc* comparisons the Tukey HSD (acronym for "honestly significant difference") test was used. A *t*-test for dependent samples was used to determine whether food preferences were related to the frequency with which capuchin monkeys received the food items during the year. The Wilcoxon matched-pairs test was used to assess whether there was a significant difference between the frequency with which monkey chow (or the familiar food) was chosen and the frequency with which monkey chow (or the familiar food) was eaten.

The Wilcoxon matched-pairs test was also used to evaluate the frequency with which monkey chow was chosen and eaten in relation to the other familiar foods. For this analysis, only the trials in which monkey chow was paired with the familiar foods were considered (a total of 156 trials).

The Mann-Whitney *U* test was used to assess differences in food choice and consumption between the sexes. Age classes were not compared because the number of juveniles (n = 5) was too low for performing statistical analysis.

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Table 2a Experiment 1: *Post hoc* comparisons between familiar foods (chosen).

	Salad*	Monkey chow*	Bread*	Pear†	Potato†	Banana†	Tangerine†
Salad		0.02	0.0001	0.0001	0.0001	0.0001	0.0001
Monkey chow			ns	0.0001	0.0001	0.0001	0.0001
Bread				0.01	0.002	0.0001	0.0001
Pear					ns	ns	0.001
Potato						ns	0.004
Banana							ns

Table 2b Experiment 1: *Post hoc* comparisons between familiar foods (eaten).

	Salad*	Monkey chow*	Bread*	Pear†	Potato†	Banana†	Tangerine†
Salad		0.04	0.001	0.0001	0.0001	0.0001	0.0001
Monkey chow			ns	0.001	0.01	0.0001	0.0001
Bread				0.02	0.002	0.0001	0.0001
Pear					ns	ns	0.0001
Potato						0.03	0.0001
Banana							ns

* everyday foods; † not-everyday foods; ns = no significant difference

The frequency with which each individual chose and ate (after having chosen) monkey chow respectively, when paired with the other familiar foods, was compared with the results obtained in Experiments 2 and 3 (for novel and ex-novel foods respectively) using the Wilcoxon matched-pairs test.

Experiment 2 Chow versus novel food

Foods

In Experiment 2, monkey chow was tested against seven novel foods: fresh blueberries, palm pith in salted water, shrimp in salted water, lychees in water, fresh lemon, soy sprouts in water and boiled artichoke (see Table 1 for the energy content of the foods). The seven novel foods had not been previously tasted by the subjects. Palm piths, shrimps, lychees and soy sprouts were washed in fresh water before presentation.

Procedure

Each capuchin was presented with seven binary choices between monkey chow and each of the seven novel foods (a total of 182 trials). The animals received only one presentation of each food combination because a food can be considered novel only once, which is when it is encountered for the first time. In each trial the food item that was chosen by the subject, and whether it was eaten or not, was scored (see above, Experiment 1).

Statistical analysis

The Wilcoxon matched-pairs test was used to assess whether there was a significant difference between the frequency with which monkey chow (or novel food) was chosen and the frequency with which monkey chow (or novel food) was eaten, and to evaluate the extent to which monkey chow was chosen and eaten compared with novel food.

The Mann-Whitney *U* test was used to assess sex differences in food choice and consumption. Age classes were not compared (see above).

Experiment 3 Chow versus ex-novel food

Foods

In Experiment 3, monkey chow was tested against seven ex-novel foods: fresh pineapple, canned meat in jelly, boiled pasta, fresh grapefruit, fresh tomato, boiled string bean and fresh savoy cabbage (see Table 1 for the energy content of the foods). Ex-novel foods had been encountered by all of the subjects during a previous experiment for the first time (Visalberghi *et al* 2003b); for this reason they could not be considered novel. The previous experiment lasted from July 2001 to January 2002, and after that experience the subjects had not encountered the seven ex-novel foods again until this experiment, which took place during May and June 2003.

Procedure

Each animal was presented with seven binary choices between monkey chow and each of the seven ex-novel foods (a total of 182 trials) (see Experiment 2 for further details). In each trial the food item that was chosen by the subject, and whether it was eaten or not, was scored (see above, Experiment 1).

Statistical analysis

The Wilcoxon matched-pairs test was used to assess the extent to which monkey chow was chosen compared with the ex-novel food items. The Wilcoxon matched-pairs test was also used to assess whether the frequency with which monkey chow (or ex-novel food) was chosen differed from the frequency with which monkey chow (or ex-novel food) was eaten.

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The Mann-Whitney U test was used to assess sex differences in food choice and consumption. Age classes were not compared (see above).

Results

General results

Food items, when chosen, were not necessarily eaten: there was a significant difference between the frequency with which a food was chosen and the frequency with which it was eaten in all the three experiments for both types of food (Figure 2). Nevertheless, whereas in Experiment 2 the number of times that the novel food was chosen was more than twice the number of times that it was eaten, the difference was less pronounced in Experiments 1 and 3, when familiar foods and ex-novel foods were paired with monkey chow.

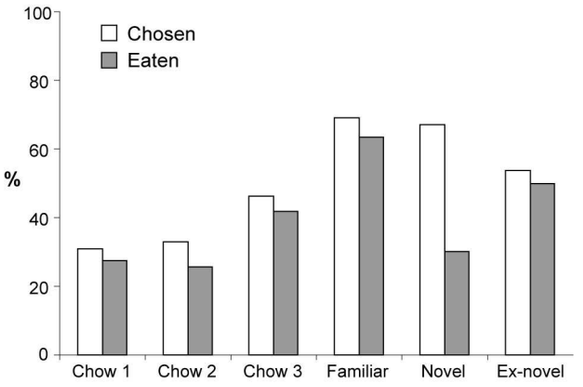
There was a significant difference in the frequency with which capuchin monkeys chose monkey chow in the three experiments (Friedman $\chi_r^2 = 9.4$, $P < 0.01$). In particular, monkey chow was chosen significantly more frequently in Experiment 3 than in both Experiment 1 (Wilcoxon test $Z = 2.2$, $P < 0.03$) and Experiment 2 ($Z = 3.1$, $P < 0.01$). Furthermore, there was a significant difference in the frequency with which capuchins ate monkey chow in the three experiments ($\chi_r^2 = 23.9$, $P < 0.0001$). In particular, monkey chow was eaten significantly more frequently in Experiment 3 than in both Experiment 1 ($Z = 4.1$, $P < 0.0001$) and Experiment 2 ($Z = 3.0$, $P < 0.01$). Monkey chow was also eaten more frequently in Experiment 1 than in Experiment 2 ($Z = 2.4$, $P < 0.05$).

Experiment 1 Chow versus familiar food

Capuchin monkeys performed a choice in 99.3% of the trials. Familiar foods were chosen significantly more frequently than monkey chow ($F_{6,150} = 38.6$, $P < 0.0001$). *Post hoc* comparisons between foods are shown in Table 2a: monkey chow was only chosen significantly more frequently when paired with lettuce. Capuchins chose significantly more 'not-everyday' foods than 'everyday' foods ($t_{25} = -19.3$, $P < 0.0001$). Similarly, familiar foods were eaten significantly more frequently than monkey chow ($F_{6,150} = 32.9$, $P < 0.0001$) and capuchins ate significantly more 'not-everyday' foods than 'everyday' foods ($t_{25} = -17.5$, $P < 0.0001$). *Post hoc* comparisons between foods are shown in Table 2b: monkey chow was only eaten significantly more frequently when paired with lettuce.

When paired with a familiar food, monkey chow was chosen in 31.2% of the trials, when a choice was performed. When chosen, monkey chow was eaten on 88.9% of the occasions. A familiar food was chosen on 68.8% and eaten on 92.8% of the occasions. Capuchins chose monkey chow significantly less frequently than the other familiar foods (median, lower and upper quartiles: other familiar food = 14.0 [10.0–15.0], monkey chow = 4.0 [3.0–8.0]; $Z = 3.4$, $P < 0.001$). Similarly, capuchins ate monkey chow significantly less frequently than the other familiar foods (other familiar food = 13.0 [10.0–14.0], monkey chow = 3.0 [2.0–7.0]; $Z = 3.3$, $P < 0.01$).

Figure 2



Percentage of trials in which monkey chow and the other foods were chosen and eaten in Experiment 1 (chow 1 and familiar food), Experiment 2 (chow 2 and novel food), and Experiment 3 (chow 3 and ex-novel food). There was a significant difference between the percentage of times that a food was chosen and the percentage of times that it was eaten (chow chosen 1 versus chow eaten 1, $Z = 3.1$, n = 26, $P < 0.001$; chow chosen 2 versus chow eaten 2, $Z = 2.5$, n = 26, $P < 0.01$; chow chosen 3 versus chow eaten 3, $Z = 1.8$, n = 26, $P < 0.05$; familiar chosen versus familiar eaten, $Z = 2.9$, n = 26, $P < 0.01$; novel chosen versus novel eaten, $Z = 4.2$, n = 26, $P < 0.0001$; ex-novel chosen versus ex-novel eaten, $Z = 2.4$, n = 26, $P < 0.01$).

There was no significant difference between males and females in food choice (monkey chow: [median, lower and upper quartiles] males = 3.0 [2.0–7.0], females = 5.0 [3.0–9.3], Mann-Whitney $U = 50.5$, $n_1 = 10$, $n_2 = 16$, ns; familiar food: males = 14.5 [10.8–15.8], females = 13.0 [8.0–14.3], $U = 54.5$, $n_1 = 10$, $n_2 = 16$, ns), and food eaten (monkey chow: males = 2.0 [1.0–5.5], females = 4.0 [3.0–8.3], $U = 43.0$, $n_1 = 10$, $n_2 = 16$, ns; familiar food: males = 13.0 [10.5–14.8], females = 12.0 [7.5–13.3], $U = 55.5$, $n_1 = 10$, $n_2 = 16$, ns).

The median, lower and upper quartile values in which monkey chow was chosen by adults were 3.0 (2.0–8.0) and by juveniles 5.0 (4.0–8.0); the corresponding values for familiar food chosen by adults were 14.0 (10.0–15.0) and by juveniles 13.0 (10.0–14.0). The median, lower and upper quartile values in which monkey chow was eaten by adults were 3.0 (2.0–7.0) and by juveniles 3.0 (3.0–6.0); the corresponding values for familiar food eaten by adults were 13.0 (10.0–14.0) and by juveniles 10.0 (10.0–12.0).

Experiment 2 Chow versus novel food

Capuchin monkeys performed a choice in 98.3% of the trials. When paired with a novel food, monkey chow was chosen 33% of the times a choice was performed. When chosen, monkey chow was eaten 78% of the times. A novel food was chosen 67% and eaten 45% of the times. Capuchins chose novel foods significantly more than monkey chow (median, lower and upper quartiles: novel food = 5.0 [3.0–6.0], monkey chow = 2.0 [0–4.0], $Z = 2.6$; $P < 0.01$). Nevertheless, capuchins did not eat

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novel foods significantly more frequently than monkey chow (novel foods: 1.5 [1.0–3.0], monkey chow = 1.0 [0–3.0]; $Z = 0.5$; $P = 0.6$).

There was no significant difference between males and females in food choice (monkey chow: [median, lower and upper quartiles] males = 0.5 [0–4.3], females = 2.0 [1.0–4.0], $U = 63.5$, $n_1 = 10$, $n_2 = 16$, ns; familiar food: males = 6.0 [2.8–7.0], females = 5.0 [3.0–6.0], $U = 64.5$, $n_1 = 10$, $n_2 = 16$, ns), or in food eaten (monkey chow: males = 0.5 [0–2.8], females = 1.0 [0–3.3], $U = 76.0$, $n_1 = 10$, $n_2 = 16$, ns; familiar food: males = 2.0 [1.0–3.8], females = 1.0 [1.0–2.0], $U = 63.5$, $n_1 = 10$, $n_2 = 16$, ns).

The median, lower and upper quartile values in which monkey chow was chosen by adults were 3.0 (1.0–5.0) and by juveniles 5.0 (1.0–5.0); the corresponding values for novel food chosen by adults were 4.0 (2.0–6.0) and by juveniles 2.0 (2.0–6.0). The median, lower and upper quartile values in which monkey chow was eaten by adults were 3.0 (0–5.0) and by juveniles 5.0 (1.0–5.0); the corresponding values for novel food eaten by adults were 4.0 (2.0–6.0) and by juveniles 2.0 (2.0–5.0).

Experiment 3 Chow versus ex-novel food

Capuchin monkeys performed a choice in 100% of the trials. When paired with an ex-novel food (see 'Materials and methods' section), monkey chow was chosen 46.1% of the times a choice was performed. When chosen, monkey chow was eaten 90.5% of the times. An ex-novel food was chosen 53.8% and eaten 92.8% of the times. However, there was no significant difference in the frequency with which ex-novel foods and monkey chow were chosen (median, lower and upper quartiles: ex-novel food = 4.0 [2.0–6.0], monkey chow = 3.0 [1.0–5.0]; $Z = 0.6$, $P = 0.6$). Similarly, there was no significant difference in the frequency with which ex-novel foods and monkey chow were eaten (median, lower and upper quartiles: ex-novel food = 3.5 [2.0–5.0], monkey chow = 3.0 [0–5.0]; $Z = 0.7$, $P = 0.5$).

There was no significant difference between males and females in food choice (monkey chow: [median, lower and upper quartiles] males = 2.0 [1.0–4.0], females = 3.0 [2.0–5.3]; $U = 68.5$, $n_1 = 10$, $n_2 = 16$, ns; familiar food: males = 5.0 [3.0–6.0], females = 4.0 [1.8–5.0]; $U = 68.5$, $n_1 = 10$, $n_2 = 16$, ns), and food eaten (monkey chow: males = 2.0 [1.0–4.0], females = 3.0 [0–5.3]; $U = 79.5$, $n_1 = 10$, $n_2 = 16$, ns; familiar food: males = 4.0 [3.0–6.0], females = 3.5 [1.8–5.0]; $U = 67.0$, $n_1 = 10$, $n_2 = 16$, ns).

The median, lower and upper quartile values in which monkey chow was chosen by adults were 3.4 (2.3–5.0) and by juveniles 2.8 (2.0–3.8); the corresponding values for ex-novel food chosen by adults were 5.4 (3.8–10.8) and by juveniles 4.6 (3.3–5.5). The median, lower and upper quartile values in which monkey chow was eaten by adults were 3.0 (2.0–5.0) and by juveniles 2.5 (1.8–3.5); the corresponding values for ex-novel food eaten by adults were 4.5 (2.3–10.0) and by juveniles 3.4 (2.2–4.6).

Discussion

Experiment 1 Chow versus familiar food

Monkey chow is manufactured to provide captive primates with all the necessary nutrients within a single food, and it contains sugars and lipids to make it more palatable. Theoretically, a food satisfying all of the animals' nutritional needs, such as monkey chow, should be preferred over other foods lacking one or more nutrients, or providing less energy. The results from this study show that, despite its higher energy content (see Table 1), monkey chow is one of the least preferred foods among the familiar foods tested in Experiment 1. Monkey chow was preferred only over lettuce, which has an energy content 14 times lower than monkey chow. A study by Flurer *et al* (1983) found that for the Callithricidae the addition of artificial flavours of natural foods (eg fruits) and sugars (eg sucrose or glucose) did not enhance the palatability of monkey chow enough to make it preferred to more palatable familiar foods, which were less nutritious.

As expected, based on the sensory-satiety model of Hetherington and Rolls (1996), the preference of capuchin monkeys towards familiar foods was strongly related to how frequently they had been available to them. Capuchins chose and ate more of those familiar foods that were not available daily compared with those that were always present in their diet. This result is supported by several anecdotal reports. For example, Hill (1960) described a capuchin that, after having eaten a great quantity of grapes (its preferred food), when offered a choice between grapes and another, less preferred food, chose the latter. Similarly, *C. xanthosternos* living in the Mulhouse Zoo in France, which receive bananas every day and lettuce only occasionally, prefer lettuce to bananas (S De Michelis, personal communication 2002).

In this experiment, we could not determine whether there was a difference between the sexes or age groups (adults versus juveniles) of capuchins in their choice and consumption of familiar foods because the number of juveniles (n = 5) was too low for performing statistical analysis. However, in the wild some sex and age differences have been reported in foraging activities, such as use of space, which sometimes result in dietary differences (*Cebus olivaceus* [Fragaszy 1986, 1990]; *Cebus apella* [Agostini & Visalberghi 2005]). These differences could be attributed to the experimental conditions used in this study: the capuchins were simply presented with a choice between two similar pieces of food. This situation rarely occurs in the wild because food choice also involves many other factors, for example foraging efficiency and decision making (eg which substrate to forage upon, at what height).

Experiment 2 Chow versus novel food

Capuchins were strongly attracted to novel foods and chose novel foods significantly more frequently than they chose monkey chow, although after being chosen, novel foods were eaten only 45% of the time. However, choice was very

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frequently followed by eating in Experiments 1 and 3. It has been reported that although captive and wild capuchins show interest towards novel foods they will eat very little of them (Visalberghi & Fragaszy 1995; Visalberghi *et al* 2003a). The present study extends this finding by showing that capuchins' choices were more directed to a novel food than to the familiar monkey chow. Attraction for an object or item on the basis of its novelty has also been demonstrated by De Lillo and Visalberghi (1994). So, captive capuchins seem to 'go for novelty', regardless of whether the choice concerns food items or objects: it is possible that this tendency is a response to the sensory limitations that captivity imposes on them.

Captive primates do not have to search for food or process it. Moreover, if fed mostly on monkey chow, they are also under-stimulated as they lack experiencing different tastes, textures, colours and odours. Compared with mature fruits and other foods present in the wild, monkey chow is visually monotonous and unstimulating. Barbiers (1985) found that adding artificial food colourings to monkey chow made it more interesting and desirable to captive orangutans. Similarly, stimulation of olfaction can be important: primates can benefit from the presentation of differently smelling foods, and a diet consisting uniquely of monkey chow — which always smells the same — can also be unstimulating (Animal and Plant Health Inspection Service 1999). Therefore, dietary monotony can be seen as a form of sensory deprivation (see Pelchat & Schaefer 2000) and it is very likely that captive primates need diverse stimuli from their diet (Poole *et al* 1999) and would benefit from the introduction of novel foods (Visalberghi *et al* 2002).

In this experiment, there was no significant difference between the sexes between choice and consumption of novel foods: this result is in line with a previous study (Visalberghi *et al* 2003b). We could not determine whether there was a difference between novel food choice and consumption between adults and juveniles, because the number of juveniles (n = 5) was too low for performing statistical analysis. However, some studies have found a difference in the response to novel foods between captive and wild capuchin monkeys of different ages: juveniles in general seem to be less neophobic than adults (Fragaszy *et al* 1997; Visalberghi *et al* 2003a).

Experiment 3 Chow versus ex-novel food

There was no significant difference in the frequency with which monkey chow was chosen and eaten when compared with ex-novel foods in Experiment 3. Monkey chow is therefore comparable, both in terms of choice and in terms of being eaten, to foods that had been novel and, afterwards, repeatedly encountered in a previous study (Visalberghi *et al* 2003b). Therefore, the preference for these foods was intermediate between novel foods and familiar ones: ex-novel foods are not as attractive as novel ones, but are not yet liked as familiar foods.

Conclusions and animal welfare implications

The diet of captive primates should not only be balanced and satisfy a species' nutritional needs, but should also be varied and contain natural foods, responding to the species' ecology (for example see Chapman & Chapman 1990; Howell *et al* 1993; Baskerville 1999; Bearder & Pitts 1999; Erkert 1999; Mendoza 1999; Poole *et al* 1999; Visalberghi & Anderson 1999). This study indicates that monkey chow, despite its high energy content and artificially increased palatability, is far from being attractive. Other familiar foods (especially if not presented daily) are chosen and eaten more frequently than monkey chow, and novel foods elicit monkeys' interest more than monkey chow.

The findings of this study have implications for the feeding husbandry of captive primates. First, because the presence in the daily diet makes a familiar food less preferred, good practice (that requires further *ad hoc* investigation) should alternate foods over time. Second, as novel stimuli promote exploration and social interest (Schapiro *et al* 1996; Noonan 1998; Visalberghi *et al* 2002), occasional presentation of novel foods could be a positive and financially economical method of providing sensory stimulation. However, diets consisting of different types of food items should be submitted to the opinion of an expert before being administered to the monkeys, to ensure that captive primates receive the necessary nutrients for all their biological needs and do not risk diseases resulting from nutritional deficiencies. In conclusion, a balance between the nutritional requirements, feeding behaviour, and food preferences would be fundamental to the development of a successful feeding program.

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