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Food preferences communicated via symbol discrimination by a California sea lion (*Zalophus californianus*)

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Abstract

This study investigates the food preferences of a single California sea lion, *Zalophus californianus*. Through operant conditioning the sea lion was taught to associate arbitrary, abstract symbols with different food types. The symbols were then used in paired comparisons to permit the sea lion to indicate and obtain its preferred food. Results indicated a preference for foods that are high in nutritional value and low in moisture. Knowledge of food preferences gained in this manner may be useful in improving the reinforcement process, providing environmental enrichment, and enhancing animal-human communication.

Introduction

In nature, animals can usually exercise choice about what they eat, and the study of the choices made often reveals an adaptive selectivity. There is increasing evidence that diverse animal species are able to evaluate potential food items by their nutrient content, and that they characteristically and preferentially select their food accordingly to optimize their nutrition (e.g., Belovsky, 1978; Rodgers & Lewis, 1985; Murphy & King, 1987; Fourcassie & Traniello, 1994).

It remains unclear however whether the sea lion, or any other marine mammal, demonstrates such nutrient-based food selectivity. Observations made on wild populations appear to indicate that California sea lions are opportunistic feeders, shifting their diets with local variations in the abundance of diverse prey species (Antonelis *et al.*, 1984; Lowry, *et al.*, 1991). Nevertheless, some authors suggest that wild sea lions at times largely ignore one abundant food item in preference for another (e.g. Dyche, 1903; King, 1983). Since different prey species provide different levels of nutrients (energy, protein, water, etc.) (Geraci, 1986), the possibility remains that, when faced with equally accessible food items, sea lions may demonstrate a selectivity reflecting a sensitivity to variations in nutrient content.

In captivity, caretakers ordinarily make judgments about what food items to provide, and the animals are left simply to accept or reject those offered items. Although efficient, this practice unfortunately hinders the animals from clearly demonstrating any food selectivity to which they may be naturally inclined. Thus, despite the abundance of marine mammals in captivity and their consequent availability for observation, the question of food selectivity in these animals has remained largely unaddressed.

Providing captive animals with food choice might both provide greater insight into the nature of the animals, and allow for better management. With knowledge of the preferences of a species, an animal might be given a more satisfying diet—one closer to that which it would have selected on its own. Furthermore, if operant conditioning is employed using food as a primary reinforcer, attention to the preferences of a subject may allow for fine-tuning of reinforcement procedures. For example, ordinary performance could be reinforced using moderately preferred foods, while exceptional responses could be reinforced by utilizing the most desired foods.

We investigated the food preferences of a single California sea lion, *Zalophus californianus*. The sea lion was taught to associate twelve arbitrary visual symbols with different types of whole and cut food. After the sea lion learned these various associations, its preferences were tested using the method of paired comparisons in which the sea lion was permitted to repeatedly indicate and obtain its choice between two items.

Methods

The subject of this study was a seven-year-old, female California sea lion which had been born and

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Table 1: Symbols, associated sounds and food items.

Symbol	Sound	Food Item
	bell	cut Capelin *Mallotus villosus*
	slide stick	cut Columbia River Smelt *Thadicus pacificus*
	penny rattle	cut Herring *Clupea harengus*
	horn	cut Mackerel *Scomber scombrus*
	bell rattle	cut Lake Smelt 1 & 2 *Osmerus mordax*
	squeak toy	cut Squid *Loligo opalescens*
	slide whistle	whole Capelin *Mallotus villosus*
	metal rattle	whole Herring *Clupea harengus*
	metal spoon in glass cup	whole Lake Smelt 2 *Osmerus mordax*
	whistle	whole Mackerel *Scomber scombrus*
	metal spoon in plastic cup	whole Squid *Loligo opalescens*
	clicker	Ice

raised in a zoological park, and had spent the previous five years at the Aquarium of Niagara. She had been previously trained to perform a variety of behaviors in educational demonstrations and shows. Testing for this project took place on a nearly daily basis over an 18 month period. During the study, the weight of the sea lion fluctuated between 73.9 kg and 89.4 kg. Testing was conducted in a dry, 80 m^2 enclosure adjacent to a 26,500 liter holding pool filled with fresh water. The sea lion always had free access to the pool during testing.

At the outset of this study, the subject was shaped (using mixed fish reinforcement) to touch her nose to a plastic stimulus card. Thereafter, she was presented with pairs of black and white symbols affixed to identical plastic cards and allowed to touch her nose to whichever one she chose. Six different food items were tested, as whole fish and as cut up pieces, and each food item was associated

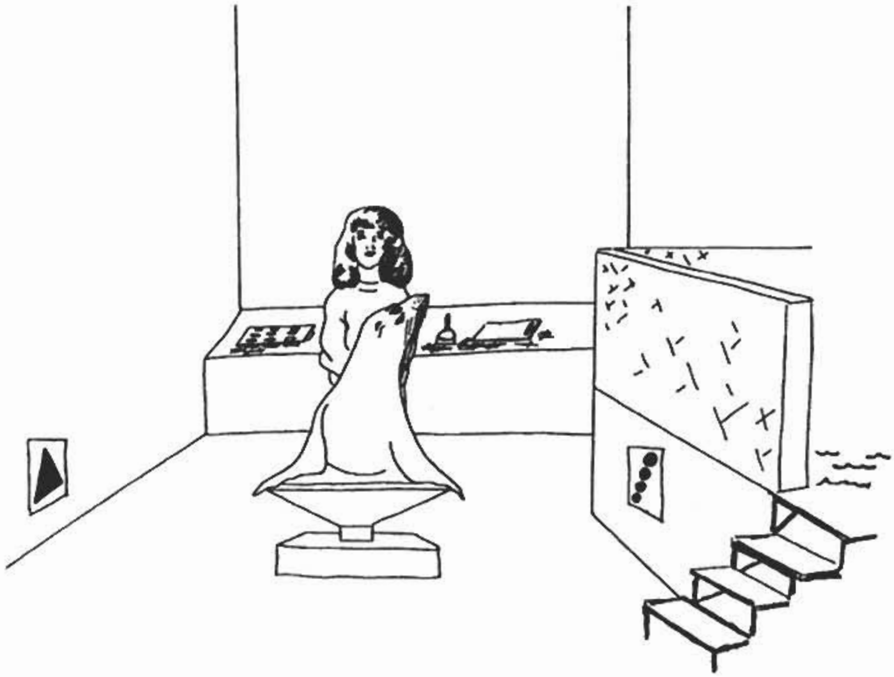

Figure 1. Testing layout.

with a unique symbol and 'bridging' sound. Table 1 presents the different symbols, their associated sounds, and the food items. Prior to this study, the sea lion was observed to apparently dislike ice. That is, when given an ice cube in place of a reinforcing fish, she would spit out the ice or even refuse to take it. In this study, in addition to the food items tested, one symbol was associated with ice cubes presented as if food.

Over a period of days, testing focused exclusively on a single pair of symbols/food items until the preference of the animal was determined, and during the days focused on a given pair, the food items being tested were omitted from the food given to the subject outside of testing sessions.

Between testing trials, the subject was taught to remain on a pedestal as depicted in Figure 1. From the pedestal, the sea lion was permitted to watch as the investigator manually hung the symbols on the enclosure walls, 130 cm to the left and right of the pedestal. The side on which each symbol was placed, and the order in which they were placed, were varied psuedorandomly and counter-balanced across trials (i.e. the sequence of presentations was determined randomly with the restrictions that each symbol appeared on the left and right equally frequently, and any given food symbol was set into place first or second equally frequently, within any ten-trial testing session). After placing the symbols, the investigator moved behind the sea lion and gave a voice command releasing the subject to select a symbol. The sea lion then left the pedestal and indicated its choice by touching one of the two symbols with its nose. Upon touching the symbol of choice, the unique sound associated with that symbol was emitted to indicate to the sea lion that the behavior was completed. The selected food type (or ice) was then given to the sea lion.

Testing took place in blocks of trials (usually 10 trials per block and two blocks per day) with each trial consisting of a paired choice. Thirty trials were conducted for each symbol pair combination, unless the preference of the sea lion was less than 90% (i.e. the subject selected the same food item on fewer than 27 of the 30 trials). In cases where a less-than-90% preference was demonstrated within the first thirty trials, one hundred trials were conducted for that particular combination.

Each new food item/symbol was initially introduced to the sea lion in sessions in which the sea lion was given the choice between that food and ice. After the subject selected the new food over the ice thirty times consecutively, the new food item became incorporated into the study. To diminish any possible influence of recent experience on the preference of the sea lion, before testing any new pair of food items, 'intermixing trials' were first conducted in which the two food items were alter-

Table 2. Food items compared as cut bits

Food items compared		Testing order	Number of trials	Preference %	Preferred item	Subject's average weight (kg)
Capelin	Columbia River smelt	4	30	97	Columbia River smelt	82.6
Capelin	Herring	3	30	100	Herring	79.9
Capelin	Mackerel	2	30	97	Mackerel	83.5
Capelin	Lake smelt 1	5	30	100	Lake smelt 1	81.9
Capelin	Squid	1	100	75	Squid	79.5
Columbia River smelt	Capelin	15	30	100	Columbia River smelt	82.3
Columbia River smelt	Herring	11	30	97	Herring	81.3
Columbia River smelt	Mackerel	14	30	90	Mackerel	82.3
Columbia River smelt	Lake smelt 1	13	100	90	Lake smelt 1	81.7
Columbia River smelt	Squid	12	30	100	Columbia River smelt	81.3
Herring	Capelin	22	30	100	Herring	78.1
Herring	Mackerel	20	100	61	Herring	77.2
Herring	Lake smelt 2	23	30	100	Herring	77.6
Herring	Squid	21	30	83	Herring	78.1
Mackerel	Capelin	16	30	100	Mackerel	80.4
Mackerel	Herring	18	100	60	Herring	84.0
Mackerel	Lake smelt 2	19	30	100	Mackerel	81.7
Mackerel	Squid	17	30	100	Mackerel	84.0
Lake smelt 2	Capelin	29	30	100	Capelin	82.3
Lake smelt 2	Herring	28	30	100	Herring	80.8
Lake smelt 2	Mackerel	30	30	100	Mackerel	80.4
Lake smelt 2	Squid	27	30	100	Squid	80.4
Lake smelt 1	Capelin	7	30	100	Lake smelt 1	82.2
Lake smelt 1	Columbia River smelt	6	100	77	Lake smelt 1	81.3
Lake smelt 1	Herring	8	30	97	Herring	81.3
Lake smelt 1	Mackerel	9	30	97	Lake smelt 1	81.7
Lake smelt 1	Squid	10	30	100	Lake smelt 1	81.7
Squid	Capelin	31	30	100	Capelin	80.4
Squid	Herring	26	30	100	Herring	79.0
Squid	Mackerel	25	30	100	Mackerel	78.1
Squid	Lake smelt 2	24	30	100	Squid	77.6

nately paired with ice until the subject selected either food item over the ice on thirty consecutive trials.

Tables 2 and 4 present the food pairs tested, and the order in which they were tested. Each food pair was tested twice, except for the pairs involving Columbia River smelt and lake smelt. During the course of this study, before all comparisons were completed, Columbia River smelt became unavailable and our original type of lake smelt was restocked by our supplier with a much smaller fish. The first lake smelt ranged in size from 5 cm to 8 cm in length, while the second lake smelt ranged in size from 2 cm to 5 cm. Accordingly, the comparisons with Columbia River smelt are incomplete and our findings before and after the lake smelt transition have questionable comparability. Although in the course of our testing the same symbol and sound were associated with both lake smelt types, in our results we report on the first and second lake smelts separately.

Results

The results of the trials comparing cut pieces are presented in Table 2. Note that the sea lion responded quite differently to the different lake smelt subtypes. She demonstrated a definite preference for the first lake smelt, choosing it over cut pieces of squid, capelin, mackerel and Columbia River smelt. By contrast, she demonstrated a definite aversion to the second lake smelt. Not only did she choose all of the food categories over the second lake smelt on every trial, but she also frequently refused to make a selection between the ice and lake smelt symbols during the intermixing sessions that occurred before the actual testing sessions.

Beyond this lake smelt dichotomy, the food preferences exhibited were generally quite stable (that is, the same results were obtained on both tests of any given pair). In the only exception, the sea

Table 3. Food items, preference quotients and food

Food item	Times tested*	Times chosen	Preference quotient	Energy kcal/kg	Oil %	Protein %	Moisture %	Ash %
Herring	10	10	1.00	1600 (700–2500)	15.5 (2–29)	18.5 (15–22)	65 (52–78)	2
Mackerel	10	7	0.70	1700 (1400–2000)	9.15 (0.3–18)	19 (13–25)	69.5 (61–78)	3
Squid	10	3	0.30	850 (850)	2 (2)	15 (12–18)	79 (74–84)	3
Capelin	11	2	0.18	950 (700–1200)	5 (2–8)	14 (13–15)	79.5 (77–82)	2
Correlation coefficients relating PQ to food composition				0.8856	0.9332	0.9153	−0.992	−0.1382

Food composition values are medians (and ranges) derived from Geraci (1986; Table 47.2).
Smelts were omitted because of the ambiguity of assigning Geraci's single entry to the three types of smelt used in this study.
*The number of times the food item appears in Table 2.

lion demonstrated a degree of ambivalence when capelin and squid pieces were compared. In the first session the subject chose squid 75% of the time; in the second session she chose capelin 100% of the time. Generally however, our results reveal clear and consistent preferences. The sea lion demonstrated a preference for cut herring over all other cut food items, and herring bits were followed in preference by lake smelt 1, mackerel, Columbia River smelt, squid, capelin, and finally lake smelt 2.

It has been shown that many other species appear to take nutrient content into account in making their food selections (cf. Murphy & King, 1985). Crude nutrient contents typical for most of our food items are provided in Geraci (1986). For the food items tested as cut pieces we computed the overall preference quotient (PQ) as the total number of trials on which that item was chosen divided by the total number of trials on which it was tested (Woodworth, 1938), and those values are presented in Table 3. For each nutrient category we then computed the correlation coefficient (r) relating median nutrient values (derived from Geraci's ranges) with the preference quotients, and these r values are presented at the bottom of Table 4. Despite the small number of data pairs, a strong positive relationship was revealed between the preferences of the sea lion and the estimated quantities of energy, oil and protein contained in the cut pieces. There was also a strong negative relationship ($r = -0.992$) between preference quotient and moisture content.

Table 4 details our findings when whole fish were tested. In this case, the sea lion demonstrated a preference for mackerel over all other food categories. Mackerel was followed in preference by herring, squid, capelin and finally lake smelt 2. For the food items presented as whole fish, we similarly computed preference quotients, and compared them to the average weight of each fish item (see Table 5). In these tests, the sea lion choices were clearly related to the size of food items ($r=0.88$). When given a choice between two items, she consistently chose the larger of the two. (For the food items compared as whole fish, we also calculated the approximate nutrient amounts contained in each food item, as the median nutrient percentages derived from Geraci (1986) multiplied by the average food item weight. Correlation coefficients relating PQ to measures of food content—all nutrients, moisture and ash—were all strongly positive in this case, doubtless reflecting the unsurprising fact that larger fish have more of essentially all components than do smaller fish.)

Discussion

Given the strong correlations between the preferences of the sea lion and food composition when cut pieces of equal size were compared (Table 4), the choices made by our sea lion do not appear to be random. Since the cut bits containing higher levels of oil and protein were generally preferred over cut bits of less nutritive items, it is tempting to conclude that, like numerous other species (cf. Murphy & King, 1985), the sea lion assesses food quality according to nutrient content. However, there was an even stronger negative relationship between preference and moisture content, perhaps indicating that the sea lion was choosing to minimize water intake. Cognizant of the fact that there is evidence that marine mammals ordinarily derive their water from their food (Ridgway, 1972), we wonder if our sea lion's choices were related to her testing conditions. Although she was primarily housed in salt water, each day around the time of testing the subject spent several hours in a fresh water pool. It is possible that as a consequence of the time spent in

Table 4. Food items compared as whole fish

Food items compared		Testing order	Number of trials	Preference %	Preferred item	Subject's average weight (kg)
Capelin	Herring	39	30	97	Herring	85.5
Capelin	Lake smelt 2	41	30	100	Capelin	89.4
Capelin	Mackerel	40	30	100	Mackerel	na
Capelin	Squid	49	30	90	Squid	74.4
Herring	Capelin	36	30	97	Herring	84.0
Herring	Lake smelt 2	32	30	97	Herring	na
Herring	Mackerel	33	84*	60	Mackerel	81.7
Herring	Squid	34	30	97	Herring	84.8
Lake smelt 2	Capelin	44	30	100	Capelin	86.2
Lake smelt 2	Herring	42	29	100	Herring	89.4
Lake smelt 2	Mackerel	45	30	100	Mackerel	81.1
Lake smelt 2	Squid	43	30	97	Squid	87.6
Mackerel	Capelin	47	30	100	Mackerel	76.4
Mackerel	Herring	46	30	90	Mackerel	78.3
Mackerel	Lake smelt 2	50	30	100	Mackerel	73.9
Mackerel	Squid	48	30	100	Mackerel	75.4
Squid	Capelin	37	100	90	Squid	84.4
Squid	Herring	57	30	100	Herring	83.0
Squid	Lake smelt 2	35	30	97	Squid	83.8
Squid	Mackerel	38	30	100	Mackerel	na

*By error Test 33 was terminated after 84 trials instead of 100.

this holding pool, she ingested sufficient fresh water to influence her food choices away from food moisture. Without further experimentation we are unable to distinguish between these two alternatives (attraction to nutrients vs avoidance of water), since among the food items in the present study there was a negative correlation between nutrient content and moisture.

We recognize that our study constitutes only a beginning. Obviously additional animals will need to be tested to determine if our findings are characteristic of the species generally, and as additional animals are tested, food-symbol pairings should be varied to ensure that any consistent food preferences revealed are independent of any particular symbols. We also know that it will be important to see if the preferences indicated by our subject are stable over time. Indeed, if our suppositions about food assessment are correct, there might be predictable variations in preferences over time. Fish used as food items are known to vary considerably in nutrient content with the seasons (e.g. Leu, *et al.*, 1981). If we are correct that sea lions take nutrient content into account, their preferences might be expected to vary as a function of these seasonal variations in content.

Table 5. Food item preference quotients and weights (whole fish)

Food item	Times tested*	Times chosen	Preference quotient	Average weight (gm)
Mackerel	8	8	1.00	276.9
Herring	7	5	0.71	86.3
Squid	7	4	0.57	59.0
Capelin	8	2	0.25	22.7
Lake smelt 2	8	0	0.00	2.3
Correlation coefficient relating PQ to weight				0.8815

*The number of times the food item appears in Table 3.

These considerations notwithstanding, these data suggest that the sea lion possesses the ability to evaluate food nutrient content and to select its food items accordingly. There has been a recent demonstration that sea lions possess a gustatory sense (Friedl *et al.*, 1990). Despite their notoriously rapid swallowing, perhaps they are nevertheless able to assess their food via the sense of taste. Of course, sensory feedback from the stomach, or the post-prandial monitoring of blood-borne nutrients, are other potential mechanisms.

It would be interesting to directly test sea lion selectivity in an experiment in which the various crude nutrient components (oil, protein and moisture) of a given food item are independently varied to see if sea lions can detect the differences and select accordingly. If so, it would be important to elucidate the degree to which each component influences the choice. It would also be interesting to test whether sea lions respond differently to variations in food-water content depending on whether they are housed in fresh or salt water.

Knowledge of food preferences gained in this manner can be utilized in a number of ways. First, if the sea lion is like many other animals and has a natural tendency to optimize its nutrition, the understanding of its preferences may yield insights which will help us to better provide for their nutrition in captivity. Second, training techniques might be improved by reserving the favorite food type of the subject as special reinforcement at selected times. This might be expected to be comparable in effect to the increasingly common practice of varying degree of reinforcement with quantity ('magnitude') of food reward (Schusterman *et al.*, 1975). Third, the provision of choice to an animal may of itself be beneficial. It can be argued that mental enrichment is provided to an animal if it is permitted to exercise a degree of control over its circumstances. During this study, our subject appeared more energetic and responsive than before this investigation began.

Fourth, this study may also open a route for future investigations of the mental lives of animals. Symbolic communication research has been conducted using a variety of animal species, including dolphins (e.g. Shyan & Herman, 1987) and sea lions (e.g. Schusterman & Krieger, 1986). By studying the ability of animals to obey commands, such investigations have revealed much about the ability of their subjects to process symbolic representations and to correctly interpret and carry out instructions. We feel that it is equally important, in work of this type, to provide a route by which an animal can communicate to the investigator information about its tastes, affinities, and natural tendencies, and we submit the present study as a model for such communication. In this paradigm the subject itself, not the investigator, determines the correct response, and thus communicates information about its nature which may not be revealed under circumstances in which humans predetermine appropriate responses. In addition to food preferences, other types of preferences could be examined by using this procedure, including the preferences of a subject for different types of reinforcement such as toys, play-time, and tactile stimulation, as well as for various environmental stimuli such as music, specific human trainers, etc. In this way we can learn more about the animals we work with and use that knowledge to take steps to enrich their lives.

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