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RAPID COMMUNICATION

One-Trial Long-Lasting Food-Aversion Learning in Wild Japanese Monkeys (*Macaca fuscata*)

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We examined how Japanese monkeys in the wild formed an aversion to food which had been paired with poison. Ten monkeys of various ages and both sexes were chosen as subjects from 105 members of the Shiga-A1 troop at Jigokudani in Shiga Heights in Japan. We gave almond nuts to each subject. Once a monkey ate 10–20 almond nuts, he was captured and moved into an injection cage. Seven experimental subjects were injected intravenously with cyclophosphamide (20 mg/kg). Three control subjects received the same treatment except that they were injected with physiological saline. About 1 hour later, all subjects were released into the troop. The tests for conditioned aversions were conducted during the next 2 days. In the tests, the experimental subjects would not eat almond nuts, while the control subjects showed no hesitation in eating them. Five of the seven experimental subjects retained perfectly the aversion to almond nuts in tests conducted 1 month and 3 months later. The one-trial long-lasting food-aversion learning shown by the wild Japanese monkeys is discussed in terms of their feeding strategy. These results also suggest that food-aversion conditioning has potential as a nonlethal method for controlling crop-raiding monkeys.

Food-aversion learning has been investigated in a wide variety of species in laboratories. Those studies indicated that animals did not eat food which had been paired with a visceral illness inducing agent. The food selection of wild animals is not always genetically determined, but might

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be acquired in part by conditioned taste aversions. However, few studies revealed the learning mechanisms of food selection in wild animals (e.g., Gustavson, Garcia, Hankins & Rusiniak, 1974). Based on previous laboratory studies on food-aversion learning in Japanese monkeys (Hasegawa & Matsuzawa, 1981; Matsuzawa & Hasegawa, 1982, 1983), we attempted to examine how wild monkeys would form an aversion to the food which had been paired with poison.

We studied a seminatural troop in Shiga Heights in the central area of Japan. This troop is called Shiga-A1 and consists of 122 individuals. The Shiga-A troop, which had been provisioned at Jigokudani since 1963, split into two troops in 1979. One troop, named the Shiga-A1 troop, continued to stay at Jigokudani. The members of the troop could be recognized individually, so that we were able to compile information about the life history of each individual. For further socioecological information on the Shiga-A1 troop and adjacent troops, refer to Wada & Ichiki (1980). The monkeys ate various parts of plants and insects available in their natural habitat. The keepers of the natural monkey park at Jigokudani provided some food at the baiting place several times a day. In summer, the monkeys were given soybeans, barley, apples, and/or other kinds of fruit. They ate only barley in winter. Persons other than the keepers were prohibited from giving any food to the monkeys.

In the middle of September 1982, we gave four kinds of novel foods (almond nuts, marshmallows, red beans, and peanuts) to each monkey except for 17 infants born in 1982. Of the 105 monkeys, 90% ate almond nuts; 43%, marshmallows; 21%, red beans; and 81%, peanuts. From these observations, we selected the preferred almond nuts as the target food to be aversively conditioned. The degree of neophobia of each monkey depends on sociological factors such as age and status of the individual (see Fig. 1). Nine monkeys (8.6% of the troop members) did not eat any of the novel foods. The leader male and most of the old females showed strong neophobia. The members of the specific matrilineal group (Na group) also showed marked neophobic responses to novel foods. The Na group is the most dominant group of the troop, suggesting that the difference in neophobic responses among matrilineal groups is probably based on the difference in social status of the groups. The 12 monkeys (11% of the troop members) which ate all four kinds of food presented were younger than 6 years old and included both sexes. The younger members seemed to be active in extending their food repertories, while the older members were conservative in their response to novel foods.

On the day after we tested each monkey's response to novel foods, we chose 10 monkeys of various ages and both sexes as subjects for food-aversion conditioning. In the previous test, those 10 monkeys ate two to four kinds of novel foods including almond nuts. First, we gave

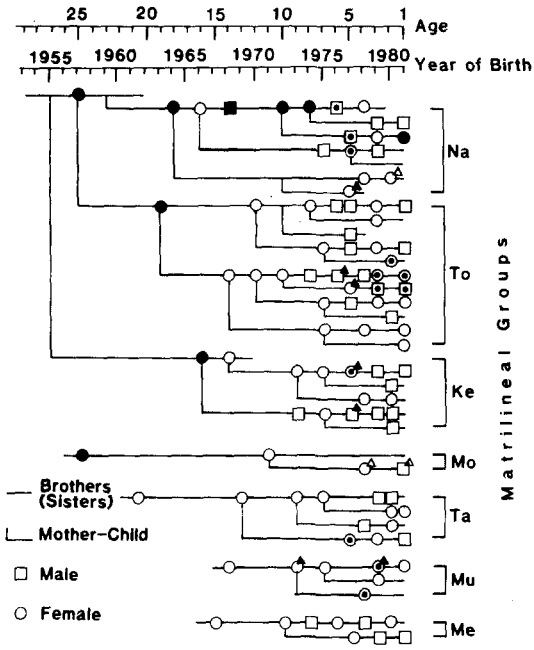

FIG. 1. Genealogy of the Shiga-A1 troop and their responses to novel foods (almond nuts, marshmallows, red beans, and peanuts). Solid circles and rectangles represent the individuals who ate no novel foods. Dotted circles and rectangles represent the individuals who ate all novel foods. The experimental subjects are indicated by solid triangles. The control subjects are indicated by open triangles. Three solitary males and seventeen infants are omitted in this figure.

almond nuts to each subject. Once the monkey ate 10–20 almond nuts, he was captured and moved into an injection cage. Seven experimental subjects were injected intravenously with cyclophosphamide (20 mg/kg). Three control subjects received the same treatment except that they were injected with physiological saline instead of cyclophosphamide. All subjects remained in the injection cage for 78 ± 13 min, and were then released. The subjects quickly ran back to the troop. The whole troop moved into the mountain forest in the evening. We could not observe the subsequent condition of each subject, but found an excreta of vomiting on the trail the next morning.

On the following 2 days, we gave almond nuts, marshmallows, red beans, peanuts, and soybeans to all 10 subjects. All experimental subjects refused to eat almond nuts on both test days. Six out of the seven experimental subjects never took almond nuts into their mouth, which indicated that they had developed an aversion to the visual as well as the gustatory aspects of the almond nuts. On the other hand, the control

subjects showed no hesitation in eating almond nuts. It means that capturing, confining, and the injection treatment itself had no effect on subsequent consumption of the almond nuts (see Table 1). Some of the experimental subjects suppressed their intake of marshmallows, red beans, and/or peanuts which they had eaten before the conditioning. Those suppressions were not caused by cyclophosphamide induced debilitation, because all of them ate the familiar soybeans at that time. The suppression might be due to the generalization of a conditioned food aversion to other novel foods.

One month later, and three months later, we reintroduced the same test sessions to test the retention of the conditioned food aversion. In both tests, five of the seven experimental subjects had retained perfectly the aversion to almond nuts. As more time elapsed since conditioning, the degree of the conditioned aversion seemed to decrease and the cue utilization changed. The experimental subjects began to eat novel foods other than the target almond nuts. Some of them took almond nuts into the mouth but did not eat them. These results indicate that the conditioned aversion is specific to almond nuts and its effect is long lasting.

We conclude that wild Japanese monkeys can form a strong aversion to one novel food after a single food–illness experience. The monkeys avoid a noxious food not only on the basis of gustatory information but also on the basis of visual information. Conditioned aversions to the almond nuts were perfectly retained for at least three months in five of

TABLE 1
Acquisition and Retention of Conditioned Aversion to Almond Nuts in Wild Japanese Monkeys

Subject	Age	Sex	Before poisoning	After poisoning			
				1st day	2nd day	1 month	3 months
Experimental							
Ibu	5	F	0	*1**	*1**	*1**	1*
Togakushi	6	M	0	*1**	*1**	*1**	*1**
Wagunah	5	F	0	*1**	1*	1	1
Keito	5	F	0	1*	1	1	1
Kehrii	5	M	0	*1**	*1**	*1*	1
Mugi	9	F	0	1*	1*	0	0
Musubi	3	F	0	1	1	0	0
Control							
Nagaenmamushi	2	F	0	0		0	0
Momiji	4	F	0	0		0	0
Moano	1	M	0	0		0	0

Note. M: male; F: female; 0, showed no aversion to almond nuts; 1, showed aversion to almond nuts (never ate them); 1*, moreover, rejected almond nuts on the basis of visual cues. *1*; moreover, showed the generalization of aversion to other novel foods.

seven experimental subjects. In contrast to the caged monkeys in the laboratory, the wild monkeys might eat various natural foods during the retention period. It is remarkable that such a varied feeding experience has little effect on extinguishing the learned aversion to a specific food. The monkeys seem to have attributed the cause of their illness to a specific food among various foods or events.

For omnivorous monkeys, the ingestion of novel foods is necessary for the extension of their food repertories. On the other hand, the ingestion makes them confront the crisis of food poisoning. The wild Japanese monkey seems to have a feeding strategy which extends its food repertories while avoiding "poisonous" food learned by taste–illness association. Such a strategy seems to increase their individual fitness, because it reduces the risk of illness and starvation.

The one-trial long-lasting effect makes it possible for food-aversion conditioning to serve as a nonlethal method for resolving the problem of crop-raiding monkeys. By controlling the food selection of monkeys artificially, we could protect rice paddies or fruit farms from the serious damage caused by monkeys. The program would spare wild Japanese monkeys, which are currently controlled by lethal methods at the rate of 2000 each year.

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