NOTE ON AVERSION LEARNING TO THE SHAPE OF FOOD BY MONKEYS

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Vervet and grivet monkeys were repeatedly tested eating bar- and circle-shaped cookies. One subject was always injected with lithium immediately after eating cookies with the circle shape and learned to avoid the circular cookies while continuing to eat the bar-shaped cookies. Another subject received similar treatment except that lithium injections were always delayed 30 minutes after access to the circle-shaped cookies. She also acquired a discriminative aversion. Aversion learning was not observed with 60-minute delayed toxicosis or with lithium injections administered unpaired with access to the cookies. The two types of cookies differed only in shape, and conditioning and test sessions were conducted in total darkness to preclude the use of visual cues. Therefore, the avoidance observed in subjects conditioned with immediate and 30-minute delayed toxicosis represents a conditioned aversion to the shape of the cookies as revealed by tactile cues. These findings illustrate that monkeys can learn to select food on the basis of tactile stimuli when such stimuli are conditioned with delayed aversive stimulation.

Key words: classical conditioning, poison-avoidance learning, taste-aversion learning, constraints on learning, long-delay learning, tactile cues, ingestion, monkeys

In many species, ingestion involves a sequence of responses including approaching the food, manipulating it with the front paws, and then taking the food in the mouth. A variety of stimuli are encountered during this ingestive sequence including the spatial cues of the food location, the visual and olfactory aspects of the food, its tactile properties, and its taste. Research on poison-avoidance learning has emphasized that poisonous foods are avoided primarily on the basis of their taste (e.g., Garcia & Koelling, 1966). According to such accounts, the taste of a poisonous material becomes associated with aversive postingestional effects, and subjects subsequently avoid eating foods with that flavor.

Poison-avoidance learning experiments typically employ flavored solutions as the conditioned stimuli (see Domjan, 1980; Logue, 1979, for recent reviews). The taste solutions are presented either in a drinking tube the subject licks to obtain the fluid or through an oral cannula. These experimental methodologies represent a simplification of the normal in-

gestive behavioral sequence. In particular, the procedures preclude handling of the food with the front paws prior to placing it in the mouth. Recently we have become interested in the possibility that animals might use the tactile properties of food in avoiding poisonous materials. We have found that rats can learn discriminative aversions to the texture of sleeves containing familiar food if ingestion of food in the textured sleeves is paired with delayed lithium toxicosis (Domjan & Hanlon, *in press*).

The present study was conducted to determine if animals that usually handle their food during the course of ingestion can also learn aversions to the shape of the food. Grivet and vervet monkeys were used, and the food consisted of sugar cookies baked in the shape of a bar and a circle. The cookies were presented in total darkness during conditioning and test trials so that their shape could be identified only by tactile cues. Ingestion of cookies of one shape was followed by lithium toxicosis. Ingestion of cookies of the other shape was not accompanied by drug treatment. The rate and latency of ingestion of each shape cookie was measured to determine whether subjects acquired a discriminative aversion to the shape that had been paired with toxicosis.

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METHOD

Subjects and Apparatus

One male and one female adult grivet monkey (*Cercopithecus ae. aethiops*) and two male adult vervet monkeys (*Cercopithecus pygerythrus*) served in the experiment. The subjects were previously used in pharmacological and physiological investigations. They were housed in individual Hartford cages undisturbed for several weeks prior to the present experiment. The rear wall of the cages could be pulled forward, forcing the subject against the front wall to permit the administration of injections. The subjects received two daily feedings of Purina Monkey Chow in food cups attached to the front of their cages. More food was provided than the animals would eat each day. However, they often upset their food dishes, spilling the food until the next feeding. All experimental sessions were conducted in the afternoon before the second feeding of the day.

Procedure

Subjects were tested individually in their home cages after being transported to a small light-sealed room near the colony room. Sugar cookies (5 to 9 g) in the shape of a bar and a circle provided the conditioned stimuli. The two cookie shapes were made from the same batter and cooked to the same hardness. The circular cookies were 5.0 to 5.5 cm in diameter. The bar cookies were 10.75 to 11.25 cm long and 2.0 to 2.5 cm wide. For each subject, one shape was designated as the CS+ stimulus, and the other shape was designated as the CS- stimulus.

Preliminary to the experiment, subjects were adapted to being squeezed to the front of their cages and to eating apples and oranges in the experimental room. During each of the next several days, they were given two CS- cookies to eat in succession with the lights in the room remaining on. The cookies were made available to the subjects on a tray attached to their cages in place of the usual food dish. After the animals learned to quickly take and eat the CS- cookies with the lights on, all experimental sessions were conducted in total darkness. The standard procedure was ineffective in getting one of the monkeys, Thisbe, to eat the CS- cookies. However, he readily ate after being allowed to watch cookies being

eaten by another subject who had completed the experiment.

During each experimental session, subjects received two cookies of the same shape, with the room lights briefly turned on in preparation for each cookie presentation. An event recorder was used to record each time the subject was heard making chewing sounds. A maximum of 10 min was allowed for the ingestion of each cookie, after which any remaining pieces of the cookie were recovered to allow measurement of how much was ingested.

On CS+ days, the lights were briefly turned on after the second cookie, and the subject was squeezed to the front of the cage and injected with 1% body weight .15 M lithium chloride in the peritoneal cavity. The lights were then turned off again, and the subject remained in darkness for approximately one hour before being returned to the colony room. On CS- days, the animals were allowed to eat two cookies having the CS- shape and were returned to the colony room without either being injected or detained for an additional hour in darkness. Subjects did not receive any experimental treatment the day after a lithium injection. The second day after a CS+ trial, they were taken to the experimental room and given either pieces of apple or orange to eat in darkness to insure that they had not acquired a total aversion to eating in the experimental situation. CS- trials were then conducted the next several days, followed by another CS+ trial.

Each subject was given a different type of experimental treatment. One male grivet monkey (Thisbe) was injected with lithium immediately after the second cookie presentation on CS+ days. The female grivet monkey (Darwina) was conditioned with a 30-min delay between the end of the second CS+ cookie presentation and injection of lithium, and a male vervet (Plato) was conditioned with a 60-min delay between the end of the second CS+ cookie and subsequent lithium treatment. The delay interval was always spent in darkness. The fourth subject, Copernicus (a male vervet monkey), did not receive either the bar or circle cookies on days when it was injected with lithium. For this subject, lithium injections were unpaired with access to the cookies. However, as with the other animals, Copernicus did not receive any experimental treatments the day after each lithium injection.

RESULTS

Two measures were used to characterize each subject's responses to the cookie presentations. The latency of eating was defined as the time between the subject picking up the cookie from the tray and making the first chewing sound. The rate of ingestion (g/min) was calculated from measures of the amount of each cookie subjects ate and the total time they were heard making chewing sounds for a particular cookie presentation. (Periods between chewing episodes were ignored in the calculation of ingestion rates.) With the exception of Darwina, who was conditioned with 30-min delayed toxicosis, the latency measure did not provide better evidence of differential responding to the CS+ and CS- cookie shapes than the rate of ingestion measure. Only data for the first cookie ingested during each session are presented, since results with the second cookie of each session were very similar.

Thisbe (0-min delay).

For Thisbe, the circle-shaped cookies served as the CS+, the bar-shaped cookies served as the CS-, and lithium injections were administered immediately after ingestion of the second CS+ cookie on conditioning days. The rates of ingestion of the first cookie during each session are shown in the top panel of Figure 1. Considerable variability occurred during the first few sessions with the CS- cookies. Ingestion of the CS+ cookies was paired with lithium toxicosis for the first time on Day 8. Thereafter, Thisbe always had a close-to-zero rate of eating when presented with the CS+ cookies. The strong aversion to the CS+ cookies was evident as early as the second time the CS+ shape was presented (on Day 12), indicating that the aversion was learned after only one conditioning trial.

After each CS+ conditioning trial, intake of the CS- cookies was temporarily suppressed, but recovered with repeated CS- sessions. This temporary depression of CS- intake cannot be attributed to an overall suppression of ingestion following toxicosis, because Thisbe readily ate pieces of an apple in the experimental situation before the CS- sessions were introduced after each lithium injection. In addition, a comparable suppression of CS- intake was not observed with 60-min delayed or unpaired lithium treatments. It seems that

Fig. 1. *Top panel:* Rates of ingestion of the first cookie presented on successive test days with the CS+ and CS- shapes for Thisbe, who was injected with lithium immediately after eating the second cookie on CS+ days. *Bottom panel:* Latencies to ingest the first cookie presented on successive test days with the CS+ and CS- shapes for Darwina, who was injected with lithium 30 min after eating the second cookie on CS+ days.

the conditioned aversion to the CS+ cookie generalized to the CS- shape (perhaps because of the common flavor of the cookies), and this generalized aversion became extinguished with repeated CS- sessions. The fact that intakes of the CS+ cookie were always depressed after intakes of the CS- had recovered indicates that a discrimination was learned between the two cookie shapes.

Darwina (30-min delay)

Darwina received treatments very similar to the procedures used with Thisbe except that for her the lithium injections were delayed for 30 min after ingestion of the second CS+

cookie on conditioning days. Once Darwina started eating a cookie, her rate of eating was comparable for the CS+ and CS- cookies. However, her latency to start eating a cookie revealed the learning of a discrimination between the CS+ and CS- shapes. The latency to ingest the first cookie of each session is presented in the bottom panel of Figure 1. Very long ingestion latencies occurred during the first two CS- sessions, but by the third session the latency was close to zero. Darwina also readily started eating the CS+ cookie the first time it was presented (on Day 7). After this first conditioning trial, the response to the CS- cookies was suppressed during the next two test days, followed by a recovery during the several subsequent CS- sessions. Response latencies remained close to zero during the next session with the CS+ cookies (Day 13), and after this session no change in response to the CS- occurred. The third exposure to the CS+ cookies occurred during Session 17, and a substantial increase in latency to ingest the CS+ cookie was observed during this trial. Darwina continued to eat the CS- cookies quickly during the next several test days. However, subsequent trials with the CS+ shape during Sessions 22 and 28 produced very long ingestion latencies. Thus, a strong differential response to the two cookie shapes became evident after three CS+ conditioning trials.

Plato (60-min delay) and Copernicus (unpaired)

For Plato lithium injections were delayed 60 min after exposure to the CS+ shape, and for Copernicus lithium treatments were given unpaired with ingestion of the sugar cookies (always 1 to 2 days after the last exposure to a cookie). One of the cookie shapes was designated as "CS-" for Copernicus, and the other was designated as "CS+." The "CS-" was presented much more often than the "CS+" to mimic the sequence of stimulus presentations used for all of the other subjects. Three CS+ conditioning trials were administered to Plato, and three lithium treatments were also given to Copernicus. Neither subject showed evidence of the development of a differential response to the two cookie shapes. Rates of ingestion were consistently above 1 g/min for both subjects and did not vary systematically as a function of the shape of the cookie. A

differential response was also not evident in their latency to start eating the first and second cookie during each session.

DISCUSSION

The present study demonstrates that grivet monkeys are able to learn aversions to tactile stimuli provided by the shape of food when ingestion results in either immediate or delayed toxicosis. The differential aversion response of subjects conditioned with immediate or 30-min delayed toxicosis (Thisbe and Darwina) could not have been mediated by olfactory or taste stimuli because the CS+ and CS- cookies were baked from the same batter. The aversions also could not have been mediated by visual stimuli because the subjects were in total darkness when each cookie was presented and eaten. At the end of each stimulus presentation, the lights were briefly turned on and remaining pieces of the cookie were removed. Failure to eat all of the cookies was more likely on CS+ test days than on CS- days, and sometimes the subjects may have seen some of the cookie leftovers before receiving the lithium injections. However, the remaining pieces always had a shape different from the circle and bar shapes of intact cookies.

The aversion learning of Thisbe and Darwina is also not likely to have resulted from nonassociative effects of the lithium injections. More than three days were allowed after each lithium injection before the subjects were again tested with the CS+ stimulus, and one or more sessions with the CS- were conducted during this period to be sure intakes had recovered. Nonassociative interpretations are also discouraged by the fact that aversions did not develop to cookies of either shape when toxicosis was delayed 60 min after ingestion of the CS+ cookies or when the lithium was administered unpaired with access to the cookie stimuli. However, it must be acknowledged that the 60-min delay and unpaired control subjects were vervet monkeys whereas the subjects that acquired aversions were grivet monkeys. Although vervet and grivet monkeys are closely related, further research is necessary to conclude that procedural rather than species differences were responsible for the absence of tactile aversions when lithium injections were delayed 60 min or presented unpaired with ingestion.

Numerous species handle food with their front paws and thereby experience its various tactile properties before taking the food in the mouth. We previously demonstrated that rats are able to learn discriminative aversions to the texture of metal sleeves containing familiar food when ingestion results in either immediate or delayed toxicosis (Domjan & Hanlon, in press). The present study demonstrates that in addition to texture, subjects are also able to learn aversions to the shape of food as experienced through tactile stimuli. These findings illustrate that animals can respond to various tactile aspects of food in learning to avoid conditioned aversive food items.

Although the present findings demonstrate aversion learning to the shape of food, further research is necessary to elucidate the role of this effect in poison-avoidance learning. In the present study subjects were injected only following exposure to the CS+ cookies but did not receive an injection following consumption of CS- cookies. Therefore, it is possible that the aversiveness of the injection was the functional unconditioned stimulus rather than the drug that was administered. We also do

not know the extent to which tactile stimuli have to be a part of a food object in order to become associated with delayed aversive stimulation. These ambiguities notwithstanding, the present study provides a new technique for the investigation of long-delay learning that does not involve taste as the conditioned stimulus.

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