Edentata 19 (2018): **61–66**
DOI: 10.2305/IUCN.CH.2018.EDENTATA-19-1.8.en
Electronic version: ISSN 1852-9208
Print version: ISSN 1413-4411
http://www.xenarthrans.org

SHORT COMMUNICATION

Giant anteater (*Myrmecophaga tridactyla*) mothers may teach their calves what "not to eat"

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Abstract During a prey scent preference experiment with captive giant anteaters living at the Nashville Zoo (USA), two anteater mothers actively inhibited their dependent calves from investigating non-nourishing but innocuous scents. An exact binomial test showed a statistically significant tendency for the dams to ignore the scents themselves after obstructing the calves' investigation. This is the first known documentation of what appears to be "teaching" behavior in Xenarthra and a rare example of a non-human animal discouraging feeding and smelling behaviors that aren't adversely affecting its young.

Keywords: captivity, feeding behavior, maternal effects, negative reinforcement, prey choice, teaching

Las hembras de oso hormiguero gigante (*Myrmecophaga tridactyla*) pueden enseñar a sus crías lo que «no quieren que coman»

Resumen Durante una investigación de preferencia de olor de presa con osos hormigueros cautivos que viven en el Zoológico de Nashville (EE.UU.), dos hembras inhibieron activamente a sus crías de investigar los olores no nutritivos pero inocuos. Se observó una tendencia estadísticamente significativa de que las hembras ignoran los aromas después de obstruir la investigación de las crías. Esta es la primera documentación conocida de lo que parece ser un comportamiento «de enseñanza» en los xenartros y un ejemplo poco común de animales no humanos desalentando comportamientos de alimentación y olfateo que no están afectando negativamente a sus crías.

Palabras clave: cautiverio, comportamiento alimentario, efectos maternos, elección de presa, enseñanza, refuerzo negativo

The feeding behavior of giant anteaters (*Myrmecophaga tridactyla*) has been well documented (*e.g.*, Redford, 1985; Medri *et al.*, 2003; Miranda *et al.*, 2003; Rodrigues *et al.*, 2008). Individuals travel between concentrations of insect prey, usually ant or termite nests, and revisit specific foraging areas periodically (Montgomery & Lubin, 1977). The literature describes females (dams) accompanied by dependent young (calves) as they forage (*e.g.*, Cabrera & Yepes, 1960; Shaw *et al.*, 1987; Eisenberg & Redford, 1999; Figel *et al.*, 2016). As for how young anteaters develop their own foraging behavior, observations only document that calves explore their surroundings by smell and taste (Bartmann, 1983; Maia, 2002; Valle Jerez & Halloy, 2003). Over the course of experimentally testing captive giant anteaters for prey scent preferences, a novel behavior was observed. Two dams, one wild-caught and one captive-born, sometimes physically blocked their respective calves from trying to investigate and feed at the experimental apparatus, which contained non-nutritious but also non-harmful chemical scents. If dams were not actively trying to influence their calves' investigatory behavior, we would expect that a dam would be equally likely to ignore her calf's behavior as interfere with it. We hypothesize that the giant anteater mothers were intervening in an attempt to teach their offspring

Table 1. Behavior of two anteater dams with their calves while investigating prey scents and control scents in an experimental apparatus. Counts were compared with exact binomial goodness-of-fit tests.

	Captive-bred dam	Wild-caught dam
Number of trials analyzed	10	13
Average number of blocks per trial (excluding trials with no blocks)	2.89	2.25
Number of trials with no blocks	1	5
Maximum number of blocks in one trial	7	5
Number of blocks with investigation	6	2
Number of blocks without investigation	20	16

what not to eat, by discouraging them from smelling and tasting the apparatus.

The experiments were performed with the captive population of adult and juvenile giant anteaters at the Nashville Zoo at Grassmere (Nashville, Tennessee, USA) and were approved by the Animal Care and Use Committees at Nashville Zoo and Middle Tennessee State University. One dam was wild-caught and one dam was captive-born, but both have been living at Nashville Zoo for several years. The calves, both females, were born two months apart at the zoo in 2017. Dams and calves were always together in the same enclosure for the experiments. We filmed anteater reactions to two-choice tests between dilute prey scents and a control scent. In trials lasting approximately 3 min, the two dams and their respective calves were presented with a U-shaped plastic pipe with two open ends (**Fig. 1A, 1B**). In each open end, we placed an aluminum tea diffuser containing a cotton ball dampened with 0.5 mL of either a dilute prey scent or a control scent, diethyl phthalate (CAS#84-66-2). This chemical was also used as the solvent (carrier) for the following prey scent dilutions: 0.05% dimethyl disulfide (CAS#624-92-0), a 0.1% 1:1 blend of limonene (CAS#138-86-3) and α-pinene (CAS#80-56-8), a 0.1% 1:1 blend of β-pinene (CAS#127-91-3) and γ-terpinene (CAS#99-85-4), 0.05% cyclohexane (CAS#110-82-7), 0.05% isovaleric acid (CAS#503-74-2), and 0.05% 2-ethyl-3(5,6)-dimethyl pyrazine (CAS#27043-05-6). The experimental chemicals were chosen because they are volatile scent odors of potential giant anteater prey genera (*Nasutitermes* termites: Himuro *et al.*, 2011; Paulino de Mello *et al.*, 2016; *Solenopsis* ants: Vander Meer *et al.*, 2010). At no time could the anteaters actually taste the chemical scents with their tongues because the scented cotton balls were completely enclosed in the aluminum tea diffuser for safety (**Fig. 1A**). The experiments relied on the anteaters' perception of the volatile odors, which are described (by human noses) as follows: sulphurous (dimethyl disulfide); pine/citrus-like (limonene, pinenes, and terpinene); petroleum-like (cyclohexane); sweaty feet/cheese-like (isovaleric acid); and musty/moldy (pyrazine). Because most of these prey chemicals do not readily dissolve in water, we chose a solvent that was relatively safe, stable, and as odorless as possible, but also would allow the volatile prey odors to escape. Diethyl phthalate is an organic solvent and a common additive to cosmetics and plastics; although it has a bitter taste, it is described as "without significant odor" and was safely used as a solvent and control in scent preference experiments with captive carnivores (Nilsson *et al.*, 2014). While this chemical may be perceived differently by giant anteaters, who have an acute sense of smell (McAdam & Way 1967), approximately the same amount of diethyl phthalate (0.5 mL) was applied both as the control and as the carrier for experimental scents that were at concentrations of 0.1% or less.

Trials were run on average once per week between March and August 2018, when calves were 3–9 months old. Dams and calves were always together in the same enclosure for the experiments. Scents were presented in random order, and over the course of the experiment each prey scent was offered in three separate trials. We used plastic gloves when applying scents and handling the pipe apparatus to reduce the influence of human odors on anteater behavior. The apparatuses were thoroughly washed and dried between animals to minimize the transfer of anteater scents and saliva between individuals. Trials were filmed with a GoPro© Hero5 Session camera (GoPro, San Mateo, USA) placed approximately 1.5 m above the apparatus. At the start of each trial, the openings at each end of the tube were set to face the anteaters and the apparatus was secured to the cage door with plastic ties.

The wild-caught dam and her calf were presented with the apparatus in 18 trials. The captive-born dam and her calf were presented with the apparatus in 20 trials. Of 38 trials total, 15 trials were discarded because the calf was either outside of the video frame or stayed on the dam's back and did not interact with the apparatus during the video.

The remaining 23 trial videos where both dam and calf interacted with the apparatus were scored by each author independently for whether and how many times the dam interfered with the calf while it attempted to place its nose into an open end of the apparatus. Dams might ignore their calf's behavior at the apparatus (no blocks during the 3-min trial), or interrupt the calf from licking or smelling at an open end by using their nose, forepaw, or whole body to move the calf's head away (**Fig. 1B–1D**). Counts of blocks were divided into two categories: either the dam blocked the calf and subsequently investigated the apparatus herself (by placing her own nose into an open end), or she blocked the calf and did not subsequently investigate the apparatus. We measured between-observer reliability by calculating a Pearson's correlation coefficient for the number of blocks counted across the 23 trials (Kaufman & Rosenthal, 2009). We used an exact binomial goodness-of-fit test to compare observed counts in each category (McDonald, 2014).

The inter-observer score correlation coefficient was 0.80. Dams ignored their calf's behavior at the apparatus and permitted them to lick and smell it without any interference in 6 of 23 trials, which is a significantly different proportion from what would be expected by chance under the null hypothesis, which predicts equal amounts of blocking and non-blocking behaviors (**Table 1**; binomial test

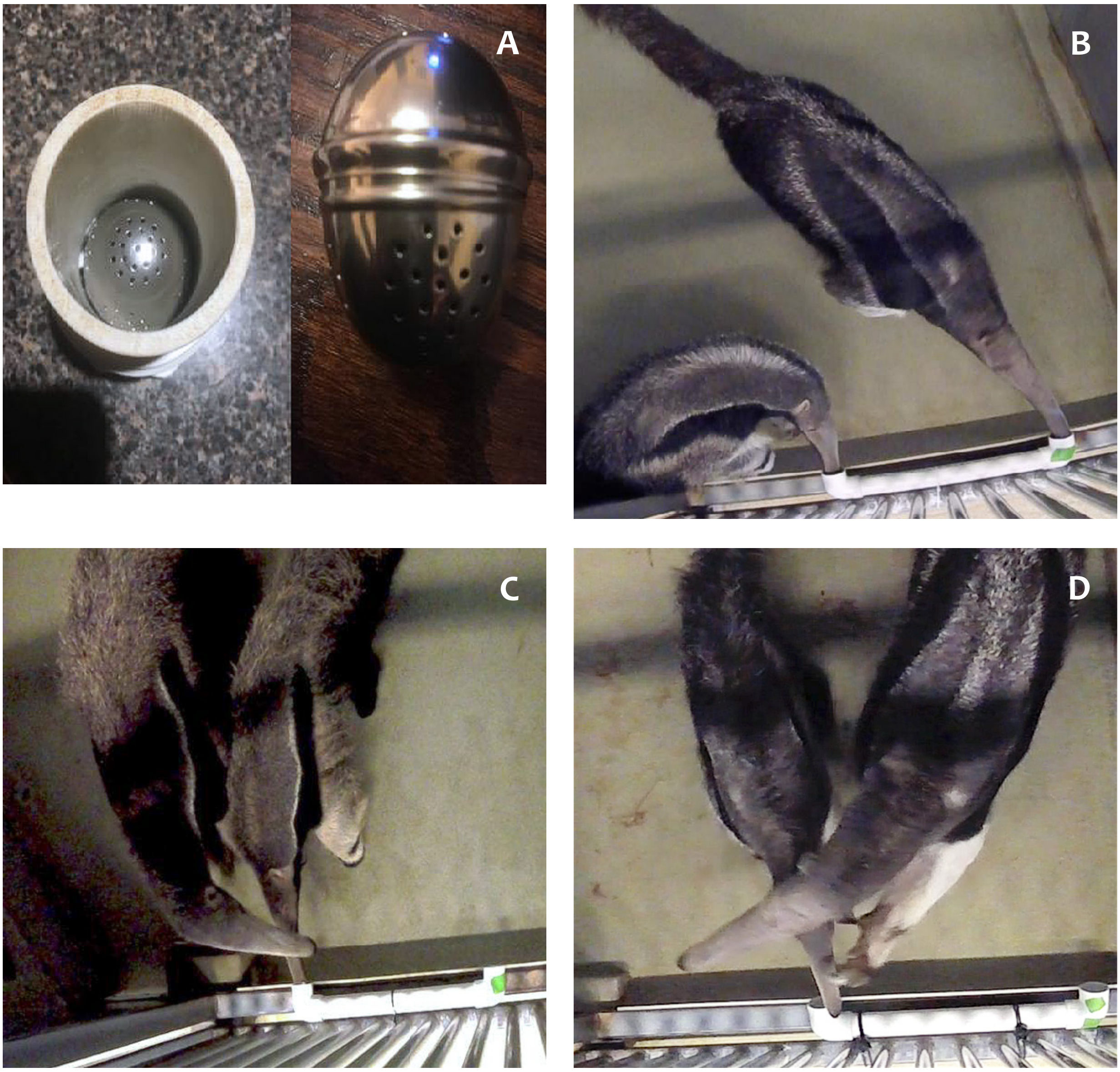

Figure 1. **A.** The tea diffuser containing a cotton ball shown as it would appear to the anteaters in one open end of the experimental apparatus; **B.** an anteater dam and her calf ignoring each other and investigating the experimental apparatus together; the green tape indicates the side with the experimental scent; **C–D.** video stills captured anteater dams blocking their calves from investigating the apparatus with the nose [**C**] and the forepaw [**D**].

p-value = 0.0023). When dams interfered with their calves' exploration, they were significantly more likely to block without investigation than block with investigation (binomial test p-value = 2.5×10^{-5}). This clearly indicates dams did not interrupt their calves' exploration (tasting and smelling) simply to lick and smell the scents themselves. Taken together, these data support our idea that mothers' behaviors were an effort to teach their offspring what "not to" taste and smell. Although full results are beyond the scope of this short communication, adult anteaters, including dams, were significantly more likely to spend more time investigating the various prey scent dilutions than the control scent (8 anteaters, 74 trials; 1-tailed sign test p-value = 0.013). By contrast, in 16 trials, the two calves tended to spend more time investigating the control scent (10 trials *vs.* 6 trials where they spent more time with the prey scents), but the difference was not statistically significant (1-tailed sign test p-value > 0.2). Over the course of our experiments, the calves grew more exploratory, and the pair would occasionally interact with the apparatus together (**Fig. 1B**). Nonetheless, the dams generally spent much less time than the full trial duration investigating the tube openings, whereas the calves persisted in trying to lick and sniff one or both sides until their mothers intervened and/or the apparatus was removed from the enclosure. Anecdotally, we also observed that dams investigated the apparatus less and less as the experimental period went on, which suggests that they learned it contained no actual food. Blocking behavior was similar in frequency, if not form, between the two mothers (**Table 1**). The captive-bred dam more often used her rostrum instead of her forepaw to move her calf's head away, and sometimes she would lick at the calf's mouth (**Fig. 1C**). The wild-caught dam more often cuffed her calf on the nose with her forepaw (**Fig. 1D**). During several trials, the anteaters seemed to be anticipating their afternoon meal by repeatedly returning to the front of the enclosure and sticking their rostrums out and occasionally licking/smelling the bottom or sides of the door. Neither dam was observed blocking her calf during that type of exploration, even if the calf was "in the way".

Young giant anteaters accompany their mothers on foraging trips for many months during the period of dependency (Eisenberg & Redford, 1999; Valle Jerez & Halloy, 2003; Rodrigues *et al.*, 2008). Presumably, calves may obtain information about the prey the mother selects without much effort on her part, both by imitating her behavior at foraging sites and by passive exposure to prey chemical cues in a manner that is similar to what occurs between mothers and offspring across taxa (*e.g.*, Jaeggi *et al.*, 2008; Vitale *et al.*, 2018). By contrast, active maternal intervention to discourage what is effectively non-profitable behavior is unexpected in this relic species. Since anteaters and most other xenarthrans are described as solitary (Eisenberg & Redford, 1999), there would not seem to be selection pressure for social learning. Only one other study in the superorder Xenarthra describes anything comparable to what we report here: female sloths (*Bradypus variegatus*) supply particular leaves to their infants, who consume those exclusively, while orphan sloths choose poisonous or otherwise inappropriate food items (Soares & Carneiro, 2002).

Active "teaching" by non-human animals in the sense of Caro & Hauser (1992) is generally uncommon although examples continue to emerge from a widening range of taxa. Cetaceans demonstrate feeding/hunting strategies and give younger animals the opportunity to practice by scaring or herding fish and then not pursuing them (Boran & Heimlich, 1999). Chimpanzees (*Pan troglodytes*) demonstrate how to manipulate tools to obtain specific food stuffs such as nuts (Boesch, 1991). Chimpanzees and gorillas (*Gorilla beringei*) will remove non-food, poisonous or otherwise hard-to-process items from their infants (reviewed by Byrne, 1999). Vervet (*Cercopithecus aethiops*) mothers will sometimes bite or slap their young when they give an inappropriate alarm call (reviewed in Caro & Hauser, 1992). When under attack by predators, muskoxen (*Ovibos moschatus*) reportedly head butt calves and may even hook them with their horns when they move too slowly into the protective circle made by adults (reviewed in Klein, 1999). In some felids, mothers hiss at or slap at their kittens to force them to hide when predators appear (reviewed in Kitchener, 1999). In our experiments, captive anteater dams modified their behavior at the experimental apparatus when their calves were present by blocking their calves from continuing to investigate while ignoring the stimuli themselves. We consider below three alternative explanations of the mothers' behavior that does not involve teaching their calves about potential food.

1) *Dams perceived the apparatus or the control diethyl phthalate as a dangerous novel object/smell.* The giant anteaters at Nashville Zoo are presented with novel toys, botanical scents, and puzzle feeders on a regular basis as part of their environmental enrichment. They have experience with a similar pipe apparatus from an enrichment study DDB conducted in 2014 (unpublished data). If anteaters had perceived the chemical odors or apparatus as a threat, they would be expected to consistently block the calves from approaching the apparatus and/or avoid it themselves. Some of the other adult anteaters in this experiment did avoid approaching the apparatus for the first several trials, but the wild-caught dam permitted her calf to explore the apparatus on the very first trial, although she did eventually interfere in that exploration. Dams' behavior differed across trials and between the two

sides of the apparatus so we feel confident in assuming they did not consider the apparatus or volatile odors of diethyl phthalate as threatening (although we also assumed it would not be considered as potential food).

2) *The blocking behaviors were related to normal grooming and play behaviors stimulated by close contact at the apparatus.* While giant anteater mothers do groom their calves and play with them by body wrestling and grasping or swiping at them with their claws (Maia, 2002), dams would most often walk back into the video frame from elsewhere in the enclosure to block the young. Also, our counts of blocks do not include any maternal contact unrelated to the calves' attempts at feeding/smelling the apparatus.

3) *Dams simply interfered when calves spent too much time "obsessing" over the apparatus.* In other words, the observed behavior wasn't about discouraging feeding/smelling behavior but is related to the habit of anteaters to move quickly from site to site rather than lingering (Montgomery & Lubin, 1977). Nevertheless, blocks did not happen at a consistent point in the trials. Blocks also did not necessarily happen when calves persisted in licking the control tea diffuser, the outside of the apparatus, the floor, the door, or other non-food items. Finally, a different dam-calf pair was observed in 2014 with avocado (a preferred treat) hidden inside a similar pipe apparatus. In two trials lasting a total of 20 min, both the dam and the calf spent the majority of the trial exploring the apparatus and all five observed blocks by the dam were followed by investigation, indicating that she was attempting to get the avocado herself. She was not observed blocking the calf from investigating any other part of the apparatus or the floor (DDB, unpublished data).

The differences between the wild-caught and captive-bred dams' behavior are slight, but may also reflect differences in the behavioral tendencies of the calves. Both calves seemed to have a preference for the control stimulus and the zoo staff suggested that regular handling of the calves from birth with plastic gloves might have primed them to prefer the smell and taste of diethyl phthalate. The current dataset does not allow us to determine whether the mothers' efforts changed their calf's exploration behavior over the long term. Furthermore, we are limited in our ability to extrapolate these behaviors observed in captivity to anteaters living in the wild. However, we believe these results show the mother anteaters actively discouraging their calves from expending energy investigating something that may have smelled interesting to the young anteaters, but was actually non-nutritious, even if innocuous. This report remains one of a very few where an animal appears to correct an exploratory behavior that isn't adversely affecting its young.

Supplementary information

Readers may see examples on YouTube© of a trial from each dam at the links that follow.

Praim 29 June 2018
(https://youtu.be/CyCxmxWptRU)

Description: Wild-born adult female giant anteater and 8-month old female calf living in a U.S. zoo. They are investigating an experimental apparatus with a 0.05% solution of isovaleric acid in diethyl phthalate on one end (with green tape) and only diethyl phthalate on the other end. The anteaters cannot taste the chemicals, only smell them. The mother interferes twice with the calf's investigation of the apparatus over the course of the trial.

Consuela 22 June 2018
(https://youtu.be/GQHj2iovKOs)

Description: Captive-born adult female giant anteater and 6-month old female calf living in a U.S. zoo. They are investigating an experimental apparatus with a 0.10% solution of 1:1 β-pinene and γ-terpinene in diethyl phthalate on one end (with green tape) and only diethyl phthalate on the other end. The anteaters cannot taste the chemicals, only smell them. The mother interferes twice with the calf's investigation of the apparatus over the course of the trial.

Acknowledgements

We are indebted to the staff at the Nashville Zoo at Grassmere, but particularly Shawna Farrington, Danielle Berthlod and Pujita Venkat for their invaluable assistance with this project. We sincerely appreciate the anonymous reviewers who provided additional background literature and helpful comments on the manuscript. MAM was supported by a summer research stipend from the National Science Foundation's Tennessee Louis Stokes Alliance for Minority Participation program.

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Received: 2 October 2018; Accepted: 8 November 2018