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ACQUISITION OF PINE CONE STRIPPING BEHAVIOUR IN BLACK RATS (*Rattus rattus*)

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ABSTRACT: Black rats (*Rattus rattus*) have begun occupying a new habitat in recent years—the Jerusalem pine (*Pinus halepensis*) forests in Israel. In this, otherwise almost sterile habitat, the sole source of nourishment for the rats is the pine seeds that can only be extracted from the cones through a complex feeding technique. Adult black rats unfamiliar with the technique (termed "naive") were unable to attain it either through trial and error or through observational learning when housed with experienced rats (termed "strippers"). In contrast, black rat pups raised by stripper mothers did learn the pine cone opening behaviour. In addition to the presence of a stripper model, however, the clues of the pine seeds themselves, as well as partially open cones, may also play a role in the acquisition of the technique. The state of the cone itself, when encountered by the rat pups, may be an important factor. Three groups of experimental animals were used: 25 pups born to naive mothers and reared on rat chow without exposure to either stripping mothers or partially opened cones; 25 pups born to naive mothers and exposed to pine cones in various stages of opening; 55 pups born to stripper mothers and exposed both to pine cones and to the presence of their mothers actively involved in stripping the cones and feeding on the seeds. We found that pine cone stripping behaviour is learned through two stages of a local enhancement effect: First, the pups are directed to the pine cones as a food resource, and then to the cone's proximal end as a starting point. The development of the stripping technique is acquired individually, with accumulating experience.

Black rats (*Rattus rattus*) have begun occupying a new habitat in recent years—the Jerusalem pine (*Pinus halepensis*) forests in Israel. In this, otherwise almost sterile habitat, the sole source of nourishment for the rats is the pine seeds that can only be extracted from the cones through a complex feeding technique. The scales must be stripped from the cone in a sequential fashion in order to expose the underlying seeds, which are tightly organized around the shaft of the cone. The rat systematically strips the scales one by one, following the spiral order around the shaft, until only the bare shaft remains (Aisner & Terkel, 1985).

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A series of experiments revealed that adult black rats unfamiliar with the technique (termed "naive") were unable to attain it either through trial and error or through observational learning when housed with experienced rats (termed "strippers"). In contrast, black rat pups raised by stripper mothers did learn the pine cone opening behaviour. Cross-fostering pups born to naive mothers on stripper mothers, and vice versa, demonstrated that the pine cone opening technique is probably acquired through a process of cultural transmission rather than genetically (Aisner & Terkel, 1985, 1991).

In addition to the presence of a stripper model, however, the clues of the pine seeds themselves, as well as partially open cones, may also play a role in the acquisition of the technique. As the state of the cone itself, when encountered by the rat pups, may be an important factor, this study was aimed at determining the influence of various stages of stripped cones on the learning process undergone by black rat pups lacking a stripper model.

METHODS

Three groups of experimental animals were used. Group 1 comprised pups born to naive mothers and reared on rat chow without exposure to either stripping mothers or partially opened cones; Group 2 comprised pups born to naive mothers and exposed to pine cones in various stages of opening; while Group 3 was comprised of pups born to stripper mothers and exposed both to pine cones and to the presence of their mothers actively involved in stripping the cones and feeding on the seeds. All pups were kept with their dams until approximately 80 days of age, at which time they were tested for their ability to strip cones.

ANIMALS AND PROCEDURES

In the first and second groups, the mothers ($n = 5$ in each group) were naive laboratory rats that had never been exposed to pine cones. Each dam raised 5 pups, housed in $35 \times 50 \times 35$ cm glass terraria, with wire mesh lids. In the first group, the pups were exposed only to rat chow and had no experience with pine cones.

In the second group, each terrarium was divided in half by a wire mesh partition with an opening (2.0 cm $\times$ 2.0 cm) large enough to permit the pups, but not the mother, to cross through the divider. Rat chow powder (Lavena, Asia & Maabarot) was available for 3 hr daily and water was supplied ad libitum. Mother and litter were housed in one half of the terrarium, and a fresh batch of eight pine cones was placed each day in the other half, with the previous batch being removed. The cones were at four different stripped stages: 2 closed; 2 stripped of scales only at the proximal end; 2 half stripped of scales; and 2 bare shafts, stripped of all

scales but still containing a few uncollected seeds. The cones had been stripped by stripper rats from other cages in our rat colony, so it is possible that the pups could have been attracted to them by the residual odour of conspecifics (Galef, 1982). Since rat chow was restricted to 3 hours daily, the pups were motivated to search for an additional source of food, and they became interested in the pine cones which had been placed in the other half of the cage.

In both Groups 1 and 2, when the pups reached 80 days of age, the mother was removed from the cage and the pups were tested for 21 days to determine their ability to strip cones. Because of the natural timidity of the wild rats, they only rarely open pine cones in the presence of an observer. Thus their ability to open and strip cones was determined indirectly by examining the state of the cones and observing the physical condition of the tested pups, which is very clearly reflected in the appearance of their dark fur; after two days of food deprivation it becomes clumped and matted. Rats that did not strip cones during the test by the second day were defined as nonlearners and were removed from the test cages and fed rat chow. Because of the structure of the cone, in which the rigid scales overlap and tightly cover the seeds, there is no way in which the rat can obtain the seeds without an efficient method of stripping the cone. Successful cone opening was defined as the ability of the rats to strip intact pine cones, leaving only the bare shaft, and obtain the seeds within as a sole source of nourishment, while maintaining normal physical condition.

Group 3 comprised 10 adult stripper female rats which raised a total of 55 pups (3–7 pups/litter). These females were experienced in stripping cones and efficiently obtaining the seeds. The pups in this group were therefore exposed both to their mothers' opening the cones and to the cones themselves in various stages of having been stripped. At the age of 60–80 days, the pups were tested as in Groups 1 and 2 for their ability to open the cones.

RESULTS

Results (Table 1) indicate that none of the pups from the first group, which had no experience with pine cones, knew how to open cones. One quarter (24%) of the pups from the second group did learn the pine cone stripping technique without having observed the behaviour from a model. Despite the lack of imitation involved in acquiring the pine cone opening behaviour, the presence of a stripper mother did facilitate learning by the pups. Two thirds (65.5%) of the pups learned the stripping technique when reared with a stripper mother for 60–70 days, compared with pups which were reared for 80 days with the stripping products only. When the data were transformed (arc sin) to adjust to normal distribution, a t test was significant ($p < .05$; Table 1).

TABLE 1
Effect of Various Raising Conditions on Pine Cone Opening Behaviour in Black Rats

Group	*No. of pups*	*No. of pups learning to open cones*	*%*
1. Pups exposed only to rat chow	25	0	0
2. Pups exposed only to pine cones	25	5	24
3. Pups exposed to pine cones and stripper mother model	55	36	65.5

DISCUSSION

The spread of the phenomenon of milk bottle opening by tits was originally reported by Fisher and Hinde (1949) and interpreted as resulting from interaction of naive birds with birds experienced in milk bottle opening (Hinde & Fisher, 1972). Although the authors emphasized that both social and nonsocial factors were involved in the spread of this behaviour, they did not uncover the mechanism by which it was acquired. Sherry and Galef (1984, 1990) show that providing birds with the experience of encountering previously opened bottles is in itself sufficient to establish the bottle opening behaviour, and thus conclude that such habits can be transmitted without involving social components.

In our own experiments too, 24% of the rat pups did learn to strip the cones when supplied only with the nonsocial component: i.e., pine cones in various stages of opening. Perhaps because of the structure of the pine cone, the partially opened cone might be the crucial factor in the learning process. The seeds in the cone are covered by hard, rigid scales, tightly overlapping around the shaft of the cone. Starting from the base, each row of scales covers the row above. The key to stripping the cone efficiently is to start at the base and systematically remove the scales in spiral order around the shaft. An already started cone may thus provide the rat pup with the correct stimulus to learning the stripping technique. Although one quarter of the pups learned to strip cones when supplied only with the nonsocial component (the cone itself), the addition of the social influence (a "stripping" model) significantly increased the proportion of pups that acquired the technique to two thirds.

The presence of a stripper mother can facilitate learning in several ways. At the time that the pups start to leave the nest and eat solid food, new behaviours such as licking and sniffing the mother's mouth appear (Ewer, 1971). While the mother is actively opening the cones, stripping

the scales and exposing the seeds to feed on them, the developing young gather round her mouth and attempt, with partial success, to obtain some seeds. At a later stage of development the pups attempt to snatch cones from the mother while she is stripping them, and they then continue the stripping process. Kemble (1984) described similar behaviours which facilitated the learning of cricket predation by northern grasshopper mouse pups (*Onychomys leucogaster*).

Food preferences of young rats have been shown to be strongly affected by the presence of adults eating near a food source (Galef, 1982). This could facilitate learning to strip pine cones by pups reared with stripper mothers. Moreover, chemical cues also act as an important stimulus for food preferences in rats (Galef, 1982), and a mother's odour on a stripped cone may provide a stronger stimulus to investigate the cone than the odour of a strange rat.

We proposed that pine cone stripping behaviour is learned through two stages of a local enhancement effect as suggested by Thorpe (1956): First, the pups are directed to the pine cones as a food resource, and then to the cone's proximal end as a starting point. The development of the stripping technique is acquired individually, with accumulating experience.

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