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EXPERIMENTS ON OLFACTORY DETECTION OF FOOD CACHES BY BLACK-BILLED MAGPIES

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ABSTRACT.—Although the importance of olfaction in birds is being increasingly recognized, its role in species with very small olfactory bulbs, such as corvids, is largely unknown. In field experiments designed to examine whether Black-billed Magpies (*Pica pica*) use olfaction to locate hidden food, we found that magpies uncovered significantly more caches of suet and raisins scented with cod liver oil than control caches. We suggest that in recovering caches, magpies use a multi-cue system that may involve both memory and visual or olfactory cues. Olfactory cues may be particularly important in finding and taking food hidden by other individuals.

In 1960, Cobb developed a way of comparing the sizes of olfactory bulbs in different species by using the ratio of the greatest diameter of the olfactory bulb to the greatest diameter of the ipsilateral cerebral hemisphere, expressed as a percent (Cobb 1960). Anatomical studies of 124 bird species have shown variation from 3% to 37% in this measure (Bang 1971). Experimental studies have revealed that species with high bulb-to-hemisphere ratios (over 28%) have well-developed abilities to use olfaction in searching for food or nesting burrows (Stager 1964; Wenzel 1968, 1971, 1972, 1982; Grubb 1972, 1974, 1979; Hutchison and Wenzel 1980; Hutchison et al., in press).

Corvids as a group show little development of the olfactory bulb (ratios below 6%), although many species cache food. Carrion feeders in particular, such as ravens, crows and magpies, might be expected to use the sense of smell in finding food and recovering caches. Caching by corvids has received much attention but there is little suggestion that olfaction is important in recovering hidden stores. The most studied species, however, have been seed cachers such as nutcrackers and jays (genera *Nucifraga, Garrulus, Aphelocoma* and *Gymnorhinus*; see Turcek and Kelso 1968, Bossema 1979, Tomback 1980, and Vander Wall 1982), and, for them, olfactory cues may be minimal. During a four-year field study of Black-billed Magpies (*Pica pica*) at Wind Cave National Park, Custer County, South Dakota (Buitron 1982, 1983) both caching and the recovery of previously-made caches were frequently observed. Carrion from road-killed black-tailed prairie dogs (*Cynomys ludovicianus*) provided the main food source for caching. These observations suggested that scent might be one of the cues used to recover caches and, especially, to steal caches made by neighboring magpies. In one instance, magpies discovered a completely hidden chicken (*Gallus domesticus*) that had begun to smell after being placed beneath a submerged rock in a spring-fed stream. The meat had been put in the "cache" when fresh, one week previously, and was discovered by magpies only after it had begun to decay.

Such suggestions of the use of olfaction in magpies led to our first experimental field trials examining the ability of Black-billed Magpies to use odor for locating food caches. Our preliminary experiments consisted of hiding equal numbers of control and experimental caches beneath the ground cover in areas frequented by foraging magpies. In these trials, magpies consistently discovered experimental caches of rotten chicken (6 of 19) or bread soaked with cod liver oil (13 of 59) more easily than control caches of fresh chicken (0 of 19) or unscented bread (1 of 49). These trials also helped us to develop ways of eliminating visual cues, such as buzzing flies or oily surfaces above caches, while still making it easy for magpies to remove the food from the cache (e.g., not burying it too deeply).

METHODS

SCENT EXPERIMENTS

In 1982, we conducted a larger scale experiment near the nest of an individually-marked pair of magpies who had become accustomed to our providing food. The trials took place in June, when magpies were feeding nestlings. Sixty caches of raisins ($n = 30$) or suet ($n = 30$) were made at about 1.5-m intervals along the edge of a semi-circular parking lot. This edge was chosen because it provided a uniform stretch of short grass and gravel that was regularly visited by the magpies.

Caches were made by boring a hole 3 cm deep with a blunt stick. Into each hole we placed either three raisins or a small piece of suet. Thirty of the caches (15 with raisins, 15 with suet) were chosen as experimentals, and to these 2 ml of cod liver oil were added. We used cod liver oil because of its distinctive odor and easy applicability in controlled doses.

All holes were covered with a piece of numbered, waterproof tape that was then hidden under a thin layer of gravel. This prevented oil from seeping to the surface in the experimental caches. Care was taken to avoid leaving any visual cues. Whether a cache was experimental or control was determined by a random drawing. The person who covered the caches was unaware of whether a cache was experimental or control, in order to avoid human bias in hiding caches.

We placed several exposed "training" caches in the experimental area to encourage magpies to search carefully; these were distributed randomly with respect to whether the nearest cache was experimental or control. In experiment 1, we hid caches 1–2 h before sunrise, before the magpies returned from their night-time roost. In 1983, we repeated the experiment using 60 caches of raisins (30 experimental and 30 control). That year the experimental area had not been pre-baited, so in experiment 2, we hid the caches during the first two hours of daylight to attract magpies to the general area by our activity. The experimental design provided a control for visual detection, since the preparations of control and experimental caches had an equal chance of being observed. In both years, we monitored the experimental site from a hill 100 m distant for several 1-h periods, and caches were checked three times a day.

MEASUREMENTS OF OLFACTORY BULBS

We dissected two salvaged adult magpies (1 female, 1 male) whose heads had been preserved in 10% formalin within 1 h of death. The brains were dissected several months later and measured with calipers, using the methods of Bang and Cobb (1968).

RESULTS

SCENT EXPERIMENTS

In the 1982 experiment, 18 of the 60 caches were discovered and eaten by magpies within 15 h. Fifteen of the 18 uncovered caches were cod liver oil-soaked experimentals ($\chi^2 = 11.4$, $P < 0.001$), and magpies repeatedly walked by unscented caches only to discover the locations of nearby scented caches (Fig. 1A). Similarly, in the 1983 repetition of this experiment, 10 of the 13 caches uncovered and eaten were experimentals (Fig. 1B, $\chi^2 = 4.8$, $0.01 < P < 0.05$).

During the experiments, several behavioral observations of magpies locating hidden caches suggested that scent was being used. In one of the preliminary experimental trials, for example, a magpie moved uphill and upwind through long grass directly toward a scented cache, which it immediately pulled out and ate. In a similar case during later trials, a magpie was walking parallel to the edge of the parking lot when he suddenly stopped, turned 90 degrees and went directly toward a scented food cache. Throughout the experiments, we found no digging marks other than directly at the cache locations.

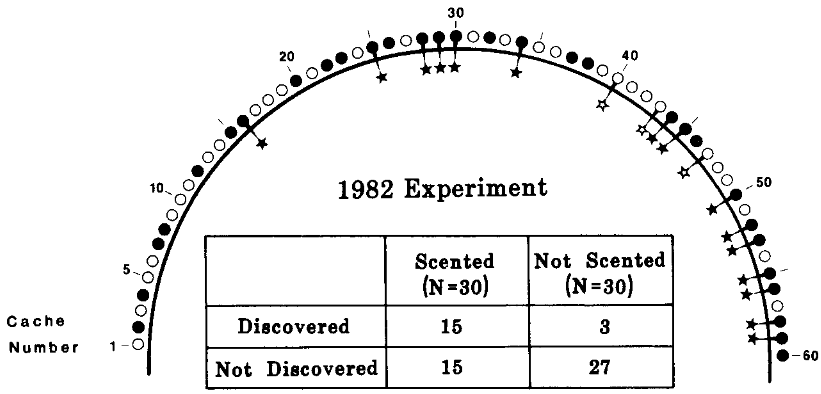
MEASUREMENTS OF OLFACTORY BULBS

The olfactory bulbs of both male and female magpie brains were very small and difficult to measure accurately. Repeated measurements of both the left hemispheres and the left olfactory bulbs yielded an average bulb : hemisphere ratio of 1.4 mm : 20.7 mm or 6.7% for the female, and 1.6 mm : 21.2 mm or 7.5% for the male.

DISCUSSION

Although measurements of the bulb : hemisphere ratios could be obtained for only two magpies and some brain shrinkage seemed to have occurred, the resulting values fall close to the range that Bang (1971) found for other corvids: 6% for Blue Jays (*Cyanocitta cristata*) and 5% for American Crows (*Corvus brachyrhynchos*). Only 11 of the 124 species that she examined had ratios smaller than 7%.

Species that have been shown to use scent for finding food or nest burrows all have had much larger bulb : hemisphere ratios (e.g., Brown Kiwis, *Apteryx australis*; Turkey Vultures, *Cathartes aura*; and several species of Procellariiformes). A larger olfactory bulb, however, does not necessarily reflect a greater sensitivity to odors. Instead, it may reflect an ability to accurately discriminate among odors of different types (Adrian 1951, Bang 1971). Domestic pigeons (*Columba livia*), with a bulb-to-hemisphere ratio in the middle range (18%; Bang 1971), discriminate odors in laboratory experiments (Shumake et al. 1969) and appear to use scent as one of the cues for homing (Papi et al. 1973, 1978; Benvenuti et al. 1973; Waldvogel et al. 1978). Members of a species with small olfactory bulbs may be sensitive to particular odors important to their survival.



1982 Experiment

	Scented (N=30)	Not Scented (N=30)
Discovered	15	3
Not Discovered	15	27

$X^2 = 11.4$, $P < 0.001$

1983 Experiment

	Scented (N=30)	Not Scented (N=30)
Discovered	10	3
Not Discovered	20	27

$X^2 = 4.8$, $P < 0.05$

FIGURE 1. Chi-square summary of the 1982 and 1983 scent experiments. Results from 1982 are diagrammed schematically to illustrate the experimental design. Sixty caches (circles) were set in a semicircle, using bait (raisins or suet) which was either scented (filled circles) or unscented (open circles). The stars designate caches uncovered by magpies.

Our field experiments using cod liver oil showed that Black-billed Magpies are able to use scent for locating hidden food caches, at least at distances of under 1 m. Because magpies were attracted to search in our experimental area by both previous experience and visual cues (the exposed "training caches"), these experiments did not attempt to establish the use of odor by magpies as a long distance cue. In the open air, we ourselves were unable to smell the cod liver oil when more than 1 m from the cache site.

The ability of magpies to use scent for finding food also may enable them to find and eat each other's caches. This seems especially likely when caching outside their territory, close to the original carcass. Of the 85 magpie caches of suet or meat we observed in 1981, 22% were within 20 m of the food source, and 60% were between 20 and 100 m.

Upon discovering a carcass, a magpie is faced with a large but ephemeral food source for which there is high intra- and interspecific competition. By quickly dispersing the carcass into numerous small caches, a magpie may be able to reduce the ability of American Crows to dominate the food supply, and also may be able to reduce overnight losses to scavengers such as coyotes (*Canis latrans*).

Within a few hours of making the original caches, magpies frequently moved the food from the first location to a new site closer to the nest, where the food was much less accessible to other birds. Caches of carrion made during the late fall or winter may have lasted for several months, if frozen, but caches made during spring and summer were likely to be short-term. Caches not used within a week of being hidden probably were lost to flies, beetles, and rodents. However, such short-term caches may have been important in enabling males to provide incubating females or hungry nestlings with a constant food supply. Both road-kills and orthopteran insects—another important food—were unpredictable and often unavailable for several consecutive days during cold and rainy weather (Buitron, unpubl. data).

Behavioral observations and experimental data have shown that many corvids, such as the Carrion Crow (*Corvus corone*), European Jay (*Garrulus glandarius*), Clark's Nutcracker (*Nucifraga columbiana*), and Eurasian Nutcracker (*N. caryocatactes*), use memory to find their seed caches (e.g., Swanberg 1951, Goodwin 1955, Bossema 1979, Balda 1980, Hewson 1981, Tomback 1980, Vander Wall 1982). Black-billed Magpies also seem to remember the exact location of many caches. Hayman (1958) saw a magpie return directly to a site where it had cached food 3 h earlier. At Wind Cave, Buitron saw magpies fly directly to a tree ($n = 4$) or bush ($n = 2$) to pull out, without hesitation, a piece of concealed food. It seems likely that magpies, like jays and nutcrackers, rely primarily on memory for relocating cached food but, when scent cues are available, they are capable of using them to pinpoint the location. Odor cues may be especially important in finding and appropriating caches made by other individuals. We have observed such "cache kleptoparasitism" both by unrelated individuals at road-kills and by mates from inside the territory. Olfaction may also be important for locating carrion, but this aspect needs further investigation.

In summary, our studies suggest that olfaction may play an important, everyday role in the behavior of Black-billed Magpies, and that this sense should be as seriously considered for birds with small olfactory bulbs as for those with large bulbs.

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