Journal of Comparative Psychology
2006, Vol. 120, No. 3, 288–293

0735-7036/06/$12.00 DOI: 10.1037/0735-7036.120.3.288

What Do Rooks (*Corvus frugilegus*) Understand About Physical Contact?

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Rooks (*Corvus frugilegus*) do not use tools, but rapidly solve tests of physical cognition. The authors tested whether rooks understand the concept of physical contact using a task comprising a clear horizontal tube containing a stick with a disk attached to it and a piece of food. The rooks chose which side to pull the stick from to make the food accessible. Two configurations were used, with either the food or disk central along the tube. All 8 rooks solved the food-central configuration, but failed the disk-central configuration. Although they did not demonstrate an understanding of contact, further tests established that they could learn to solve these tasks provided there were salient stick cues. This result may arise because sticks are ecologically important for rooks.

Keywords: corvid, folk physics, rook, contact, rapid learning

The study of physical cognition in animals attempts to demonstrate what animals might understand about the various properties of their physical environment, such as gravity, shape, and the way that objects causally interact with each other. It has been suggested that the presence of complex physical cognition in animals is related to the ability to use tools because frequency of tool use is correlated with increased relative volume of overall brain size as well as with specific brain areas such as the isocortex and nidopallium (Lefebvre, Nicolakakis, & Boire, 2002; Reader & Laland, 2002). If tool use was the sole selection pressure for the evolution of physical cognition, then nontool users should fail physical tasks. However, results from tamarins (Hauser, 1997; Hauser, Kralik, & Botto-Mahan, 1999; Santos, Miller, & Hauser, 2003) and rooks (Seed, Tebbich, Emery, & Clayton, in press; Tebbich, Seed, Emery, & Clayton, in press), both of which have not demonstrated tool use in the wild, suggest otherwise. It has been proposed that living in complex societies may facilitate the evolution of a general intelligence, of which physical cognition is one form (Humphrey, 1976). Alternatively, these nontool-using species may encounter other types of physical problems in their natural environment, which may have driven an understanding of specific forms of physical cognition, such as gravity, or a more general understanding of folk physics. Indeed, rooks appear to live in a highly complex society (Emery, 2004; Goodwin, 1976); they play with and manipulate objects (N. S. Clayton, & N. J. Emery, personal communication, 2005); and they are innovative generalists (Cramp & Perrins, 1994; Lefebvre, Reader, & Sol, 2004).

Furthermore, rooks have been tested on the trap tube paradigm (as devised by Limongelli, Boysen, & Visalberghi, 1995; Visalberghi & Limongelli, 1994). This task required the subject to retrieve a food reward from inside a horizontal clear Perspex tube by pushing it out with a stick while avoiding a trap set in the bottom of the tube. The apparatus was modified for non-tool-using rooks so that the tool (a stick with two disks attached with a gap in between them where the food was placed) was already located inside the tube, and the rook had to simply pull the stick from one side or the other to move the food reward (Tebbich et al., in press). The rooks learned how to solve this task very rapidly, requiring fewer trials than other animals tested on the original design (chimpanzees, Limongelli et al., 1995; woodpecker finches, Tebbich & Bshary, 2004; and capuchins, Visalberghi & Limongelli, 1994).

Rooks may have been capable of solving the trap tube problem due to their natural propensity to investigate and make large holes in the ground while caching, pilfering, and recovering food (Goodwin, 1976). The present study examines what rooks may understand about the nature of the connection between food and an object that aids in its retrieval. Previous experiments investigating physical contact have taken the form of support problems or raking problems. The former, based on Willatts' (1984) experiments, involved pulling cloths on which an object rested. This type of task has been performed with tamarins, which were able to recognize whether food was on a piece of cloth (as opposed to beside it) and whether there was connection between the cloth being pulled and the cloth with the food on it (Hauser et al., 1999). Similar experiments have been given to chimpanzees, which preferred to pull in a platform with a banana on it rather than a platform with the banana to the side of it, yet were unable to appreciate the need for contact between a tool and a peg on a platform (Povinelli, 2000).

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This work was supported by grants from the Biotechnology and Biological Sciences Research Council, the Royal Society, and the University of Cambridge. Anne E. Helme was supported by a Biotechnology and Biological Sciences Research Council studentship. Nathan J. Emery was supported by a Royal Society University research fellowship. These experiments comply with the United Kingdom Home Office regulations concerning animal research and welfare as well as with the University of Cambridge regulations on the use of animals. We thank Amanda Seed and Anthony Dickinson for comments on the article, Ian Millar for constructing the apparatus, Ros McCarthy for help collecting the nestlings, and Selvino de Kort and Sabine Tebbich for help in hand-raising the rooks.

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The only avian species yet tested on a support paradigm is the yellow-crowned parakeet, which preferred to pull a napkin supporting food rather than an empty napkin (Funk, 2002). Parakeets and ravens have demonstrated the ability to pull up food on strings, with some ravens being able to respond to functional connections between string and reward (Funk, 2002; Heinrich, 1995). Dogs also learned to pull in a string to retrieve food, yet appeared to show no understanding of physical contact (Osthaus, Lea, & Slater, 2005).

Animals that use tools in the wild may be expected to encode something about the nature of the contact between the tool and the food. Povinelli (2000) tested chimpanzees on various raking tasks, and after repeated trials, some were able to correctly choose a functional rake over an inverted rake. Capuchins, which are also natural tool users, were able to choose functional hook tools in a variety of situations to rake in a food reward (Fujita, Kuroshima, & Asai, 2003). Some animals that do not use tools in the wild have also been tested with raking implements. Hauser (1997) investigated the abilities of tamarins with a battery of tasks in which various functional and nonfunctional properties of the tools used to rake in food were altered. The relevant experiment in this case involved candy cane-shaped tools and a piece of food located inside or outside of the hook area. After extensive training, the tamarins chose the former tool condition more often. A later study showed that this recognition of the functional properties of tools was not an innate ability, but a result of generalization from experience (Spaulding & Hauser, 2005). Parakeets learned how to use a stick or rake to obtain seeds from outside their cages (Funk, 2002). As far as we are aware, no other avian species has been examined for its understanding of physical contact using a raking paradigm.

These findings imply that some nonhuman animals, and not necessarily tool users, understand something about the spatial relationship between a food item and the object used to obtain it. However, there are at least three different ways in which animals might solve a tool-based task. Although some animals might have a full understanding of folk physics, as most adult humans do, these tool-based tasks do not require such an ability. For example, the animals may form generalized rules that enable them to transfer solutions to new problems, or they may be capable of solving problems through associative learning. These three methods can be illustrated with reference to the trap tube paradigm. Animals may have a concept of gravity and solidity that enables them to understand the function of the trap. Alternatively, they may use a generalized rule such as win stay/lose shift, whereby if on their first trial they pull away from the trap and are rewarded, they will continue to always pull away from it, yet if on their first trial they pull toward the trap and are not rewarded, they will try another method on their second trial. Finally, they may simply learn that the position of an asymmetrical cue predicts the direction in which they have to pull. Providing animals with a series of tests and transfers can help elicit which method they are using. If rooks are capable of finding a general and transferable solution to tool-based tasks, then they may have a level of problem-solving ability that has generalized from different experiences of the physical properties of their environment. If rooks are incapable of solving these types of task, then their physical abilities may be limited to those specific domains where learning about physics is adaptive.

Experiment 1

In the present study, we made use of the fact that the rooks already had extensive experience in pulling sticks within Perspex tubes (Seed et al., in press). In the previous trap tube experiments, the stick had two disks between which the food reward was placed. In the present apparatus, the main modification was to use a stick with a single disk so that the piece of food was moved only if the stick was pulled from one end, that is, the side that put the disk in contact with the food. To investigate how much the rooks understand about physical contact, two versions of the apparatus were used (see Figure 1). Four birds started with Tube A (food-central configuration) and 4 with Tube B (disk-central configuration). If the birds attend only to the position of the food or the disk relative to the tube, then it should take a long time for the birds to transfer the solution to the second tube after solving the first. If the birds use the positions of the food and disk relative to one another, then they should be able to transfer the solution to the second tube very rapidly.

Method

Subjects. We tested 8 hand-raised rooks (*Corvus frugilegus*), approximately 18 months of age at the start of testing. There were 7 females birds (Nuryef, Curie, Cooper, Fonteyn, Guillem, Callas, and Fry) and 1 male bird (Cook). All the birds had previously been tested in the two-trap tube experiment (Seed et al., in press). They were housed in an outdoor aviary measuring 20 m long × 4.5 m wide × 3 m high. They were captured once each week and brought into indoor compartments measuring 2 m long × 1 m wide × 2 m high for a period of 3 consecutive days. The indoor aviary was climate controlled and had a 12:12-hr light–dark cycle. The birds had ad lib access to food and water outside of trials; however, food was restricted during test sessions.

Training procedure. All 8 birds were given 10 training trials with a Plexiglas tube (175 mm long × 40 mm wide) that was fixed horizontally onto a wooden block (200 mm long × 25 mm high). The ends of the tube were sealed with rubber bungs, and the base of the tube contained holes through which food could fall. A stick measuring 110 mm long with a Perspex disk attached to its end was placed in the tube. Pulling on the stick would result in food dropping through one of the holes in the tube. The position of the stick was randomized and counterbalanced so that the stick was on the left for five trials and on the right for five trials. If, during the test phase, the bird responded on the same side for 20 consecutive trials, it was said to have developed a side bias and was given another 10 training trials with this tube to try to break it.

Test procedure. The test apparatus was the same tube used in training, but had a stick measuring 230 mm long with a disk attached to its center. The apparatus provided a forced-choice procedure because after the first

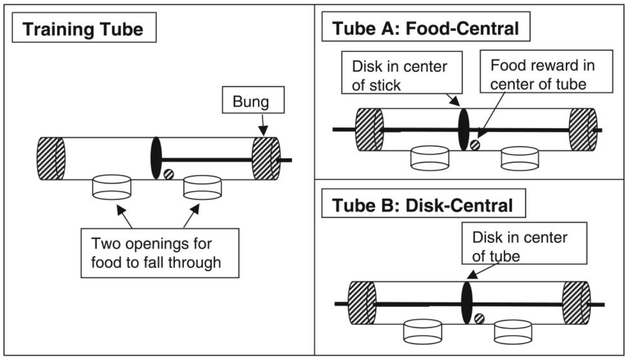

Figure 1. Training tube, Tube A configuration with the food central, and Tube B configuration with the disk central.

choice had been made and the stick was pulled from one end, the other end was trapped inside the tube behind the bung, preventing the rook from secondarily pulling the stick in the opposite direction to retrieve the food. There were two configurations of the apparatus. In Tube A, the food was located centrally between the two traps, with the disk off center. In Tube B, the disk was located centrally between the traps, with the food off center (see Figure 1). The rooks Curie, Nuryef, Fry, and Cook were tested on Tube A first, and the rooks Cooper, Fonteyn, Guillem, and Callas were tested on Tube B first.

Trials were conducted in blocks of 10. The position of the food or disk was randomized and counterbalanced right and left so that there were five in each position per block. Food rewards used were mealworms, egg yolks, sausages, grapes, or flapjacks, depending on the preference of individual birds. As these items are differently shaped, the placement of the reward was such that it occupied the space 1 cm to one side of the disk. The apparatus was assembled out of view of the rooks and placed inside the aviary, centralized on a shelf. Trials were recorded onto video using a Sony DV camcorder and viewed on a color monitor. Each trial was scored as successful or unsuccessful based on whether food was retrieved. Birds were given 5 min to make an approach; if no approach was made in this time, the trial was restarted. There was a 5-min intertrial interval. A bird was deemed to have passed the tube problem if it made a significant number of correct responses across two subsequent blocks of 10 trials (binomial test, null hypothesis = 50%; with $\alpha = .05$, significance is 15 out of 20 or higher). We also required a performance of at least 7 out of 10 correct per block of 10 trials. If a bird did not satisfy this requirement within 150 trials, then tests on that particular tube ceased, and the bird was said to have failed the task.

Results and Discussion

Figure 2 shows the performance for each individual. The score for each trial block is in the form of the number of trials correct out of 10. Fonteyn was given 180 trials on Tube B due to her surprisingly high result of 9 out of 10 correct in Trials 141–150, but this was probably a chance result, as her performance subsequently dropped again to 5 out of 10 correct. The 4 rooks that started with Tube A were compared with the 4 that previously had 150 trials on Tube B to see whether there were any differences in performance. The order of tubes learned had no detectable effect on the speed with which the birds learned each task. The 8 birds were compared for the number of blocks of trials taken to reach criterion on Tube A (15 out of 20 on two consecutive blocks, Mann–Whitney U two-tailed, $U = 7$, $p > .05$).

The main result is that the rooks passed the food-central (Tube A) task only. The tasks were identical apart from the fact that the disk and stick provided cues about the direction in which to pull in the food-central task and the food position was the asymmetrical cue in the disk-central (Tube B) task. If the rooks were attending to the conjunction of the disk and the food, then success on one task should have been transferable to the other, but this was not shown because Nuryef, Curie, Cook, and Fry, which passed the food-central task, could not subsequently pass the disk-central task. To solve the food-central task, the birds could learn the relationship "pull from the side farthest from the disk" or "pull from the side with the shortest amount of stick protruding." This behavior was particularly evident in the strategy Fonteyn appeared to be using. Once she had solved the food-central task, her method involved walking along a branch parallel to the apparatus shelf and looking at the tube from both left and right angles before deciding from which side to pull.

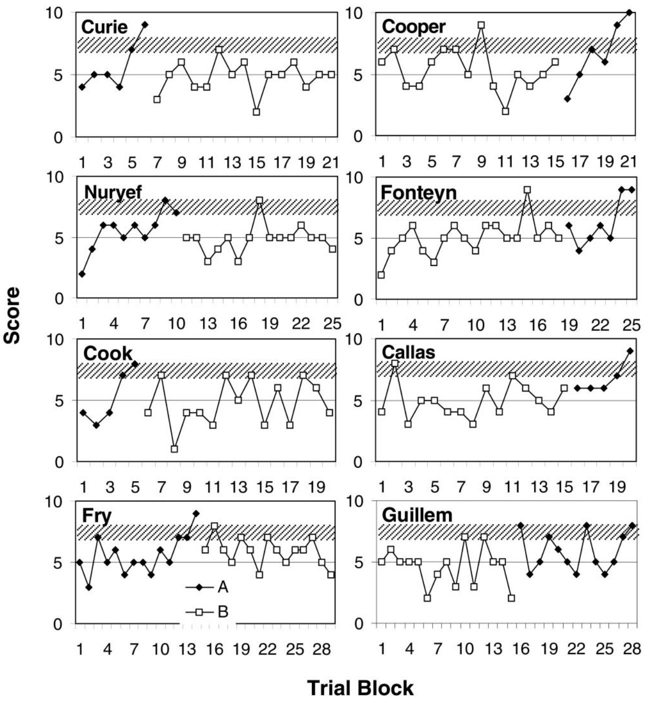

Figure 2. Experiment 1: number of trials taken to pass Tubes A and B and score per block in 10 trials for individual birds. Hatched bars indicate regions of significance; two consecutive points must fall in or above the bar for the rook to have passed.

The results from the first experiment do not rule out the possibility that the rooks might have understood something about contact. They may have performed more successfully on Tube A because there was something in that task that was directing their attention to the correct part of the problem. Therefore, we ran further tests to determine exactly what aspects of the apparatus the rooks were responding to.

Experiment 2

To investigate whether the rooks solved Tube A by understanding anything about contact or whether they were just using visual discriminatory cues, we provided tests manipulating the relative positions of the disk, stick, and food to the tube.

Method

Subjects. Four of the rooks (Guillem, Callas, Cook, and Fry) were tested on the four transfer tubes (Tubes C–F, see Figure 3). All 4 of these birds had passed Tube A and failed Tube B.

Procedure. The first transfer tube, Tube C, was a modified form of Tube B in which an extra offset black disk was added to the stick. If the rooks had learned a relationship between disk position and being rewarded while solving the Tube A task, they should transfer the solution quickly to Tube C because it provides the same cue. Tube D was the same as Tube A, but the stick was symmetrical in relation to the tube, so if the stick was the salient cue, the rooks should fail to transfer the solution to Tube D. Tube E was the same as Tube B with the stick asymmetrical, so the only cue available was the stick position. Tube F was the same as Tube E, but in the previous stick-asymmetrical experiments, the birds always had to pull from

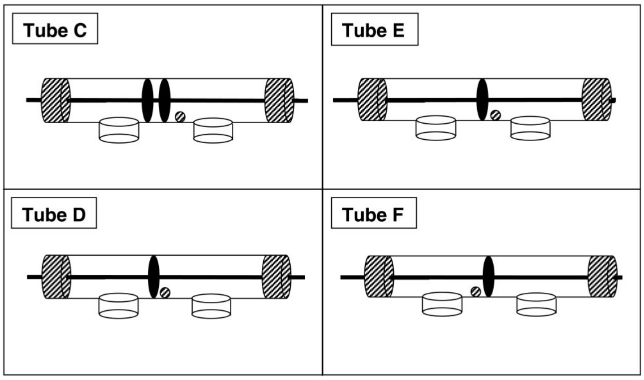

Figure 3. Tubes C–F. The conditions were as follows: Tube C, stick symmetrical and two black disks (one central and one offset); Tube D, stick symmetrical and disk offset; Tube E, asymmetrical stick, disk central, and pull from the short end of the stick; and Tube F, stick symmetrical, disk central, and pull from the long end of the stick.

the short end of the stick, whereas in the Tube F experiments, they had to pull from the long end.

The method was identical to that used in Experiment 1. As we were investigating the birds' current knowledge (as opposed to whether they could learn the new tasks if given sufficient training), each bird was given just 20 trials per tube. Before being tested on each Tubes C–F, the birds were given at least 10 trials on Tube A to provide baseline data. This allowed us to check that the environmental testing conditions were constant; if a bird failed Tube A, then the conditions may have changed.

Results and Discussion

Figure 4 shows the performance of 4 birds that took part in both Experiments 1 and 2 on Tubes C–F and retests on Tube A. The score for each block is in the form of the number of correct trials out of 10. The data show that the rooks continued to consistently pass Tube A, with the possible exception of Guillem. When the disk alone provided cues (Tubes C and D), the rooks could not solve the problem; however, this was not the case when only the stick provided a cue (Tube E). All 4 rooks appeared to use stick length as a directional pulling cue. However, when stick length became a false indicator, that is, now the longer length of stick had to be pulled (Tube F), none of the rooks transferred what they had learned to this new cue. In fact, 3 out of 4 rooks performed at a level significantly worse than chance (Guillem and Callas, 5 out of 20, binomial test, two-tailed, $p < .05$; Cook, 1 out of 20, binomial test, two-tailed, $p < .01$).

General Discussion

Taken together, the results of these two experiments provide no indication that the rooks understood anything about the concept of contact. Instead, the findings demonstrate that they were capable of the fairly rapid learning of a relationship in order to obtain food and that they attended to simple visual cues that allowed them to apply this relationship.

The rooks used stick length as a cue to solve this task even though there were other potential cues available. The black disk was just as reliable a cue and was found to be relevant in previous experiments (Seed et al., in press). All 4 birds tested on Tubes C–F

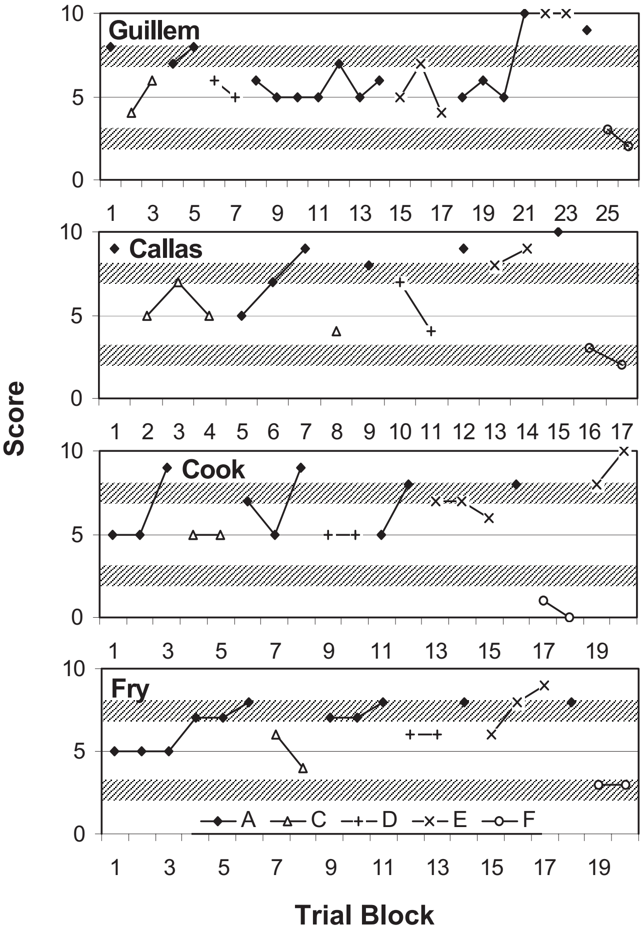

Figure 4. Experiment 2: score out of 10 per block of trials on Tubes C–F and retests on Tube A for individual birds. Hatched bars indicate regions of significance; two consecutive points must fall in or above the upper bar for the rook to have passed. Guillem developed a side bias. After not being able to solve Tube D, she did not reach significance over 70 trials when retested on Tube A. She was biased for four out of seven blocks (pulled on one side 9 or 10 times out of 10). We tried her on Tube E to see whether a new tube would break her bias habit. She could not pass Tube E. We then gave her more training on the training tube, and she eventually managed to pass Tube A again, after which she passed Tube E and performed significantly badly on Tube F. Callas was initially given 30 trials on Tube C due to getting the high result of 7 out of 10 on the second block. Her drop down to 5 out of 10 was initially blamed on her temporary movement into a different testing compartment. She was retested on Tube A until she regained baseline, but scored 4 out 10 only on Tube C, suggesting an inability to solve it. Fry was given 30 trials on Tube E. This was because she was right-biased (9 out of 10 on the right) in the first block of 10, but had lost the bias and scored 8 out of 10 in the second block, so she was given the chance to reach significance over the last 20 trials. Cook was given 30 trials because he scored 7 out 10 in his first two blocks. He was unable to reach significance, however. He could still solve Tube A, and when subsequently tested on Tube F, he performed significantly badly, indicating that he was using the cue of stick length. When retested on Tube E, he was able to pass it.

showed a preference for using stick cues over disk cues. One reason for this could be that sticks are ecologically salient for rooks, as sticks are a component of their intricately crafted and durable nests and hence draw their attention. During the breeding season especially, rooks in our captive groups will regularly manipulate, pilfer, and fight over sticks (A. E. Helme, personal observation, 2005). A second reason could be that the stick is the part of the apparatus that the rooks directly manipulated, as they only indirectly caused the movement of the disk and food, and therefore, it may be that the rooks were more likely to attend to the properties of the stick compared with these other cues.

When the stick did not provide a cue (Tubes B–D), the rooks did not attempt to use a different type of cue to aid them and were therefore never able to solve the task. All the rooks had taken part in other physical cognition tasks that were dependent on pulling sticks to gain access to food (Seed et al., in press). In these tasks, they had learned that pulling a stick always made the food move, as the food was trapped between two disks. This relationship would have to be altered for the rooks to understand anything about physical contact and how it relates to unidirectional raking, as only pulling the stick so that the disk would make contact with the food resulted in gaining access to the food.

It is clear that the rooks in this study had no initial understanding of the concept of contact and that they were learning relationships in order to solve the problem. An important observation from this experiment is that when the rooks were presented with their first tube, they were not constrained to learning a general rule about the nature of the food and tool. A simple relationship, "pull the short end of the stick," provides maximum success on Tube A and so may be easier to learn and may subsequently obscure the birds' ability to learn a more general rule they can apply to later variations of the tube. However, it is notable that the 4 rooks given Tube B to start with never learned any relationship to enable them to solve that task.

In conclusion, our results suggest that these rooks were unable to solve the problem of contact in this current form. This is surprising because they could solve the trap tube that capuchins and several chimpanzees could not, and they were able to learn these tasks more quickly than any of the primates tested to date (Seed et al., in press; Tebbich et al., in press). Understanding the configuration of tool and food is something that is not necessarily particular to tool users, as the nontool-using tamarins and marmosets were able to solve physical contact problems involving the use of tools (Hauser, 1997; Spaulding & Hauser, 2005). However, a recent article has shown that, in this particular task, capuchins, which are tool users in the wild, outperformed the nontool-using tamarins by being better able to manipulate the tools and even access rewards when the tool is "incorrectly" placed (Cummins-Sebree & Fragaszy, 2005). As in the case of dogs (Osthaus et al., 2005), having to use an object to pull food toward itself is unlikely to be something that a rook encounters in its natural life. It would be interesting to use this paradigm to examine whether tool users demonstrate improved results. Possible candidates would be chimpanzees or tool-using birds such as New Caledonian crows.

There may be more appropriate ways of testing what a rook understands of the functional relationships between objects. As rooks have lots of experience with sticks in the form of nest building, it might be expected that they have an appreciation of how sticks have to balance together to form an interwoven structure and, once this is made, which sticks are able to be removed without the structure collapsing. However, Nicolakakis and Lefebvre (2000) did not find a significant correlation between nesting innovations and forebrain size, suggesting that nest construction may not be under cognitive control, as believed by Hansell (2000). Furthermore, it would be interesting to develop a paradigm whereby an animal can learn a rule relative to only the properties of contact, and not a simple associative relationship in the first instance, and then see whether it is capable of transferring this rule to other situations.

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Received October 12, 2005
Revision received January 20, 2006
Accepted January 30, 2006 ■