The Auk 112(4):994-1003, 1995

AN EXPERIMENTAL INVESTIGATION OF INSIGHT IN COMMON RAVENS (*CORVUS CORAX*)

BERND HEINRICH
Department of Zoology, University of Vermont, Burlington, Vermont 05405, USA

ABSTRACT.—I presented four groups of Common Ravens (*Corvus corax*) with a problem that they had never encountered before. Could they demonstrate the solution to this problem without first practicing or learning the correct sequence of intermediary steps? The problem posed was the reaching of food suspended by a string. The solution required perching above the string and the food, reaching down, pulling up a loop of string, setting the looped-up string onto the perch, stepping onto the string, releasing the string with the bill while simultaneously applying pressure with the foot onto it, then reaching down again to repeat the cycle six to eight times in that precise order before finally securing a piece of dried meat. The results varied enormously between individuals. However, typically a bird approached the string nervously, pecked or briefly yanked on the string, repeated the approach when given another opportunity, extinguished the approach behavior, or suddenly did the entire string-pulling sequence correctly. One of the wild birds performed the entire sequence correctly on his first approach to the string, even though no other bird of that group had shown the behavior. After a bird had acquired the behavior it thereafter performed the behavior correctly without fail. Other behaviors were associated with successful string pulling. From their first trial, the four hand-reared individuals dropped the meat attached to string (and perch) if they were shooed from the perch. In contrast, other birds that were handed the food attached to string attempted to fly off with it, and it required five to nine trials before they refused to do so, apparently learning the consequences of this behavior. Other problems related to food presented on the dangling string also were solved without first overtly trying out the alternatives. These problems involved: (1) crossing the string with food with another string that held a rock; (2) using a novel string with food, next to the previously-rewarded "old" string; and (3) having food on string next to a rock on string, but with insertion of the string on the perch now displaced laterally. In contrast, the birds performed very poorly at some tasks where simple trial-and-error learning quickly would have resulted in appropriate responses. For example, three birds never once (in 79 trials) pulled the correct string in the crossed-strings experiments that another mustered with no trials. The results are discussed in terms of possible insight and alternative mechanisms, including innate behavior and learning. *Received 22 June 1994, accepted 31 August 1994.*

ACCORDING TO WEBSTER'S dictionary, insight is defined as "the power or act of seeing into a situation." Because one cannot examine directly the subjective experience of an animal, demonstrating insight is highly problematical. Insight can be shown indirectly to play a role in a behavior where learning and/or responses present from birth can be eliminated. However, this is a difficult task because each behavior is likely based on a varying spectrum of all the above. Thus, insight is operationally impossible to demonstrate, especially in all ecologically-relevant common tasks, where it might be expected to be most common, because the organism can be expected also to have been programmed to perform them.

Insight cannot be excluded as occurring in many, if any, birds or mammals. However, given the operational difficulties when inferred, it only can be inferred in a complex behavior (i.e. one that involves a series of many different steps not encountered in the wild). Furthermore, the many different steps must contribute to a goal or a solution to a problem. Any one of the individual steps may or may not be learned or inherited, because the key is not in the learning of the steps, but in their assembly into a unique coherent pattern that the animal has never performed before.

It is extremely rare to witness behavior that cannot be explained, plausibly or otherwise, by either the possibility of its being learned or inherited. Nevertheless, the possibility of mental awareness—of seeing into a situation—has been considered for some birds (Pepperberg 1991, Ristau 1991, Griffin 1992).

No bird has been more acclaimed as having insight than the Common Raven (*Corvus corax*).

The examples presuming to show insight include counting ability (Koehler 1943, 1951), tool use (Janes 1976, Montevecchi 1978), prey flushing (Malloy 1968), and teamwork (Bent 1964: 196). Nevertheless, most of these reports are anecdotal and, as suggested by Heinrich (1988, 1989), alternative hypotheses to insight are not excluded.

Here, I describe a set of observations on Common Ravens that were presented with a problem they had never encountered before: food suspended from a long string. Ravens, like parrots, have the capacity to grasp objects with their bill and feet. Given this capacity, I expected that they would be able to grasp the string, pull it, and use their feet to hold it. However, the problem consisted of assembling these behaviors into a repetitive pattern with the goal of gaining food.

In order to reach the food, the birds needed to reach down from a perch, pull up on the string, place a pulled-up loop of string onto their perch, step up with one foot, place this foot onto the pulled-up portion of string, release the bill from the string to reach down again, pull up on the string, etc., so as to repeat the exact cycle at least five times.

Methods

Most of the detailed behavioral observations refer to a group of five birds that were hand reared from nestlings. The behavioral experiments were conducted when they were approximately 1.5 years of age in a 90 m^3 aviary attached at a 2 × 1.5 m window of my home so I could observe from inside the house. This aviary contained a shed, small trees, natural ground cover, and horizontal poles for perches. The poles from which food was suspended were approximately 3 m above the ground.

These five birds were identified by conspicuous plastic colored and numbered patagial tags. In order of dominance rank the birds were: 5 (♂), 4 (♂), 3 (♀), 30 (♀), 27 (♀). In general, in any one group, only the most dominant birds could gain access to the food, because they chased off subordinates. However, unless otherwise indicated, I provided several strings with food at the same time so that the dominant birds could not monopolize access. (Nevertheless, dominance still played a role because birds could not fly off with pulled-up meat, and when a subordinate had pulled up meat it was approached by dominants who attempted to take the meat. The seemingly obvious solution of examining one bird at a time was not used because isolated birds were even more hesitant to approach strings than birds in groups.)

The strings used were twisted sisal twine, except where otherwise indicated. In one experiment, food was on a string on the snow outside a chicken-wire screen. However, in all other experiments the bait was suspended 70 cm below one of the perches or poles. Different individual strings and different attachment points were used throughout the experiments between different trials. In some trials, as indicated, each string holding meat was paired with another string holding a rock of similar mass. Except in the later trials (as indicated), the meat was air-dried hard salami to minimize the possibility that the birds would rip off pieces by flying by and grabbing it. Except in one observation where food was left on string for wild birds in the field, I was always present when strings or bait on string were available so that no birds could learn by practicing without my knowledge.

Within each group, food prior to the trials was equally available to all; hence, motivation to access the food should have been similar. Calf carcasses were supplied *ad libidum*, but removed at least an hour prior to any observations.

Results

Starting to pull up string.—For approximately 15 h from 1 to 6 December, 1990, I presented the five birds with a series of opportunities on successive days to take pieces of meat suspended by string from the horizontal perches. In the first trial of 6 h on 1 December, two strings with meat were provided and all of the birds eventually walked along the perch and examined the meat dangling below them.

Bird 3 was the first to peck at the string holding the meat, and to yank at it laterally. After five unsuccessful attempts to reach/obtain the meat from the perch by pecking and yanking at the string from above, this bird examined the meat from the ground instead, then jumped-flew up five times to grasp the meat in its bill, all the while dangling from it without letting go. Using this clumsy method, she apparently was able to tear off a few very small bits of meat and, over the next six days, whenever meat was presented on a string, she attempted no other method.

Bird 27 only once pecked at the meat-bearing string from the top on the first day. Like Bird 3, she subsequently grabbed the dangling meat by jumping/flying at it, to then tug at it while suspended in midair. Also, like Bird 3, during six days she tried no other method after the pattern was established on the first day.

On the first day, Bird 4, like Bird 3, pecked

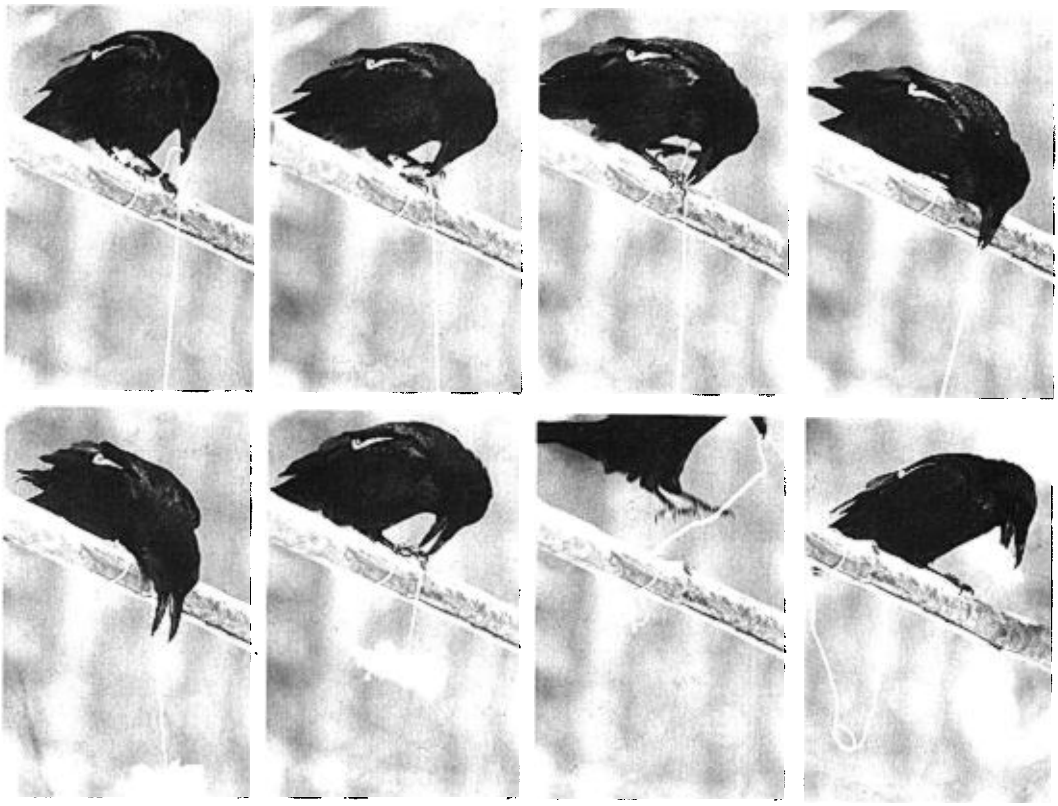

Fig. 1. Sequence of photographs showing straight pull-up behavior, where bird reaches down and brings up successive loops of string, then holds down loops pulled up before reaching again.

or yanked at the meat-bearing string, after Bird 3 had done so (but unlike Bird 3, he did not jump-fly at it). He then appeared to abandon all attempts to get the meat, but 6 h later again tried the same behavior. This time, however, after one of these yanks of the string, the bird put one foot on this pulled-up string, reached down and pulled up another length of string, to step on it again after backing up another step along the perch, to repeat the process until reaching the meat. That is, it almost "instantly" performed a behavioral sequence of at least six steps (reach, grab, pull up, set down, step on, let go, reach down, etc.) that had to be repeated without mistake at least five more times (for 30 steps total) with no apparent trial-and-error learning for most if not all of these steps, chaining these steps together into a single unbroken sequence. After this first success (on 1 December), Bird 4 immediately pulled up meat (Fig. 1) without hesitation in subsequent trials and, on this and for the next five days (2–6 December), had a monopoly of quick access to meat suspended from string. This bird at no time jumped at the meat from the ground, as Birds 3 and 27 continued to do.

Bird 5 also pecked at the string (twice) during the 6 h on the first day. Like Bird 4, he also pulled it laterally, but then failed to step on it so as to be able to release his bill for a second pull. However, after Bird 4 had pulled up meat, Bird 5 closely followed this bird and, for the next four days (now 1 h/day), he never attempted to access meat that was provided simultaneously on several strings. Instead, his only feeding strategy was to take meat that Bird 4 pulled up. Finally, on the feeding trials of the sixth day, Bird 5 at first ineffectually pecked at the top of the meat-bearing string and then also yanked laterally. On the third such attempt, he also stepped onto the pulled-up string, freeing his bill to pull again. As with Bird 4 five days previously, he now completed the entire repetitive sequence correctly all at once. After his

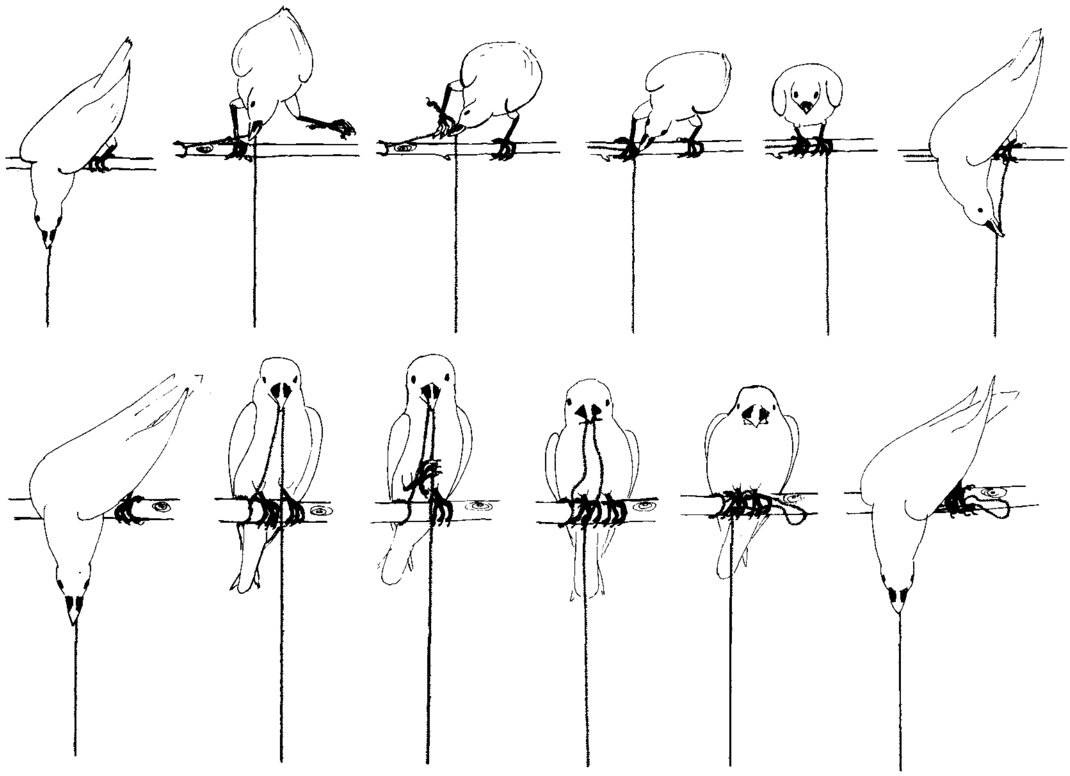

Fig. 2. Diagrams of Common Ravens using two pull-up techniques: (top) lateral step; (bottom) straight pull-up. (The rare white raven in diagram notwithstanding, all of the experimental birds were black.)

first successful trial, I chased him from the meat before he had a chance to feed. He dropped the meat, but within seconds returned. He repeated the entire behavior of pulling up the meat in six consecutive trials within about 10 min, even though I presented the meat each time from different strings in different locations. He may have been rewarded in reaching meat, but he was not allowed to feed until the last trial.

Until the end of the experiments, these two birds (4 and 5) always pulled the string laterally, stepping on it after pulling it onto the perch so that most of the string was stretched out along the horizontal perch until the meat was reached (Fig. 1). In contrast, when Birds 3 and 30 later started pulling up meat (on 23 and 30 December, respectively), they always pulled the string straight up so that consecutive loops were piled directly under their feet (Fig. 2). (Data from subsequent groups showed no sex-specific patterns.)

Bird 30, a very subordinate bird, did not even peck the string holding the meat until the sixth day of trials, when she pecked it twice. Her only access to meat during the experimental trials was by grabbing scraps left by the other four birds, or by occasionally stealing from them. She never jumped at the meat or attempted to pull any up until much later (30 December; Table 1). Her reluctance was probably not due to satiation, because in the intervals between trials she was the last to have access to the food that was then provided. Also, after Bird 4 was able to reach the meat (1 December), I simultaneously provided several (up to five) different meats on strings, so that while Bird 4 was pulling up and feeding from one, there were four other meat stations available.

In all four ravens (3, 4, 5, and 30) that could finally access the food on the string, the transition from no success (ignoring the food or merely yanking at the string) to constant reliable access (pulling up the meat) occurred with no demonstrable trial-and-error learning as regards the process itself. However, I had the impression that, with practice, they pulled the meat up more quickly and efficiently because they reached it in about five long pull-ups rather

TABLE 1. Frequency of first yank to string holding meat (M), rock (R), or thread (T) on separate approaches to paired presentations of meat and rock in seven separate series of trials, five with paired vertical strings, and two (C, D) with strings laid out onto the snow where the birds had to pull the meat toward them through a wire fence. In all other trials, strings were suspended from a perch.

Trial	December date	Test	Bird 3	Bird 4	Bird 5	Bird 30
A	1–13	Parallel rock and meat from perch	0	12M, 10R	14M, 14R	0
B	25	Meat pulled laterally to dangling rock	0	24M, 12R	10M, 9R	0
C	27	Meat and rock parallel on snow outside wire screen	12M, 11R	5M, 3R	4M, 4R	0
D	28	As in C above	21M, 10R	16M, 9R	8M, 12R	0
E	30–31[a]	As in A above	5M, 8R	20M, 3R	33M, 3R	30M, 7R
F	31	Like in B, except meat pulled laterally beyond dangling rock	0M, 3R, 9T	17M, 4R, 9T	0M, 17R, 21T	0M, 17R, 12T
G	31	As in A and E, but meat on novel string	9M, 0R	16M, 0R	6M, 1R	1M, 0R

[a] First date on which Birds 3 and 30 exhibited pulling behavior from horizontal perch.

than seven to eight short ones as in the beginning. Following these trials, I attempted to test more specifically what the birds "knew." These tests had no direct relationship to the previous problem of whether they could assemble repetitive behaviors to solve a problem since they refer to single acts only.

Flying with the meat.—Ravens that are interrupted with a small piece of meat that they are feeding on almost always fly off with it in their bill, to continue feeding elsewhere. But what if the meat is tied to string? Do the birds "know" that the string on which they pull is attached to the food? One way to determine this is if they simultaneously acquire another behavior without trials. For example, rather than flying off with pulled-up meat solidly attached to the string, the birds always began to feed on it on that portion of the perch where they pulled it up. I routinely shooed them away (in order to repeat the experiment before they fed) and, in over 100 trials, I never saw Birds 3, 4, 5, or 30 attempt to fly off with a piece of meat they had pulled up. That is, in these birds, no trials were needed to learn how to avoid the punishment of having their head yanked violently in flight. Bird 27, however, served as an instructive contrast. As indicated already, this bird never pulled up meat, but it once stole it from another bird that had pulled it up. She then flew off with this meat in her bill, to be caught short after about a 0.5 m off the perch. After that, she did not come near food on the string again.

Two captive American Crows (*C. brachyrhynchos*) behaved similarly to Bird 27, although they were less hesitant at strings. The crows almost instantly grabbed meat attached to string when it was laid onto the perch (even though they had ignored it for a month when it was left dangling, after I had given up watching to see pulling responses). Invariably, they also attempted to fly off with it. However, it required five and nine trials, respectively, before the two crows had learned to drop the meat when startled, instead of flying off with it.

Initial string tug.—Did the ravens attempt to get meat by an arbitrary series of yanks on just any string near the bait? Up to this phase in my series of experiments, all of the strings the birds encountered had meat attached, and the birds perhaps had learned to approach string (any string) and pull it up and expect food. I then provided a "blank" string (i.e. one without meat but a rock attached instead) next to each string with meat. Combining horizontal strings laid onto the ground and hanging vertical strings (see Table 1, A and C), the birds (3, 4 and 5) gave their initial pulls at paired strings randomly (total of 38 meat vs. 35 rock). However, they never pulled a rock up or in. After they gave a "wrong" string a tug, they always then switched to grab the meat-bearing string, which was then always pulled all the way up or in. (The tests of this series, however, refer only to the first or the initial tug.)

Therefore, one may conclude that, although the ravens may have been conditioned previously to expect food from string (and therefore to no longer look before starting to pull), they nevertheless only continued to pull on a string if they saw the meat attached to it either move or come closer to them. Their hasty first yank on the first string they came to may have been due to carelessness, since in previous trials it had not been necessary for them to check closely for the string-meat connection before pulling.

Crossed strings.—Given that I had made it necessary for the birds to discriminate between strings, it was now possible to ask if they observed the functional connection between the meat and the string, or if they based their choice only on the previous experience of pulling the string directly above the meat. To differentiate between these two possibilities, I displaced food 15 cm laterally from the point of attachment to the perch (by tying a thin black thread to it and pulling the meat within 4 to 5 cm of an empty string). Thus, if the birds pulled up on the string above the food rewards, as always before they would now pull the string with the rock attached (see Table 1, B). However, if they looked to see what was attached to the string, they should in this novel situation need to approach and pull up string laterally to the meat, rather than that closest over it as always before.

The results of this experiment (Table 1, B) again demonstrate the birds' individuality. Bird 5 continued to pick the strings randomly (10 meat vs. 9 rock), while Bird 4, who on the first trial chose food- and rock-strings randomly in 22 trials, now picked the right string twice as often as the rock (24 vs. 12). As before, both birds only pulled up the food-laden string. After three birds (4, 5, 30) showed convincing discrimination (Table 1, E) in their initial yanks on the correct strings, I asked the question of whether they recognized the connection between the meat and the string in a different way. I now crossed the strings to displace the meat-bearing string 40 cm laterally from its place of insertion on the perch (Table 1, F). This situation appeared to make the birds pause and gaze at the string before pulling, and they also attacked the fine thread I had used to pull the meat-bearing twine laterally. However, of the four individuals, Bird 4 overwhelmingly (17 vs. 4) pulled the correct string, even though the strings were crossed. In contrast, Birds 3, 5, and 30 never once pulled the correct meat-bearing string in a total of 79 trials (Table 1, F). As before, they pulled only the string closest to the meat (or the thread). These results show that in these birds the alternatives of which string to pull were not neutral. The strong tendency of these birds to pull the string closest to the meat continued to assume far more importance than subsequent trial-and-error learning, or else they should, after making 79 "mistakes" of pulling on the wrong string, quickly have become retrained to pull on the string lateral to the bait. Instead, they continued to make the same mistake. Although these results do not necessarily relate to insight, they indicate that different individuals may exhibit identical phenotypic behavior (i.e. choosing the correct string when two are dangled side by side) on at least two different criteria. In one case, the criterion involved pulling on string closest to meat and, in the other, it was instead to pull on the string to which the food was connected.

Novel string.—The birds up to now had pulled up meat only on one kind of string (twine). Were they conditioned to pull twine string (for which they had been rewarded exclusively) or would they pull string of a conspicuously different kind for which they had never once been rewarded? To find out, I continued to provide light-colored twine string as a control, but provided the reward on new dark green, woven shoelaces. The results were clear-cut; even though the birds previously had been rewarded only when pulling the twine, they pulled almost exclusively on the green shoelaces (32 correct vs. 1 incorrect trial in the four birds; Table 1, G). Instead of their performance deteriorating in pulling the correct string, they had now greatly improved their performance, and they had done so without trials. They had learned previously that food was provided not on a particular string, but on string connected to food. (I presume the improvement in performance likely was due to a greater ability to visually track the two strings when several dissimilar ones were dangled simultaneously close together.)

Heft.—To evaluate whether the string-pulling birds understood the functional relationships between what they were doing and the effects of their actions, I conducted one further test. They were given the choice of 200 g of meat on one string versus a partially-skinned sheep's head (mass of 2 kg) on another string. (The birds had fed on two other sheep heads during the previous week, so they were familiar and habituated to this food.) Might they know (without trials) that they would be unable to pull up the sheep's head, or would they randomly pull the two strings until they learned which yielded an immediate reward?

On the first trials, on 19 January, Birds 4 and 5 each pulled twice on the string with the small piece of meat (M). Bird 3 pulled at M four times, and jumped up from the ground at the sheep's head (SH) three times. That is, in eight responses, none involved the bird trying to pull on the string with the SH.

To find out if the birds were inhibited from pulling on the string leading to the SH, I tied the string with the meat to the SH so that pulling on the M also would pull on the SH. In this situation, Bird 4 pulled once on the string with M, and Bird 3 pulled on both (17 times on M, and 7 times on SH) and jumped up at the SH twice. Therefore, there was no inhibition to pulling on the string that led to the SH. The birds also were not afraid of the SH itself; when I untied the string with the head from the perch, Birds 3, 4 and 5 immediately approached the head on the ground and/or they pulled on the now horizontal string attached to the head.

After establishing that the birds had not been afraid of the head as such, or of pulling on the string attached to it, I again suspended the SH from the perch as before. Again, Birds 4 and 5 pulled only on the meat (three times each), and Bird 3 pulled it once, while flying six times at the SH and flying eight times at the M.

The above tests and results were repeated the following day. The SH and M were suspended side by side. As before, the birds made no attempt to pull up the SH. Three birds pulled only on the string with M (Bird 4, eight times; Bird 5, seven times; Bird 30, five times). Bird 3 jumped up at the SH 6 times and at the M 10 times; it pulled on the M string 5 times, and on the SH string twice. As on the day before, I then untied the string with the SH from the perch and lowered it to the ground; within 10 s all four birds were feeding on it, now totally ignoring the piece of meat on the string that had attracted their nearly exclusive attention moments before. I conclude that the birds had no fear of the SH that they desired to feed on, but (without trials) they preferred to try to pull up on what was a food reward of considerably lower value. Therefore, in this the sixth in a series of different novel problems to which the ravens were presented, they performed the appropriate behavior without first overtly trying the inappropriate alternatives.

Juvenile experience?—In another group of hand-reared birds string pulling was examined (in four individuals) for 1 h each on both 13 and 17 July 1993, when they were approximately two months out of the nest. At this age young, ravens are not yet highly neophobic (Heinrich, 1995), and all four birds approached the strings without hesitation. They repeatedly looked down at the meat from their perches and persistently pecked and yanked on the strings. However, none of the birds showed any string-pulling behavior.

I retested three of the birds (one had left) on 17 September 1995. During the intervening two years and two months, the birds had been in captivity and had not been exposed to food on string. All three birds pulled up or were able to pull up meat on string within several seconds (two birds) or 5 min (one bird) after they approached the string. (A fourth highly subordinate wild bird did not approach the strings.) None of the birds approached the same strings when they were dangled bare for 1 h before and after the above experiment.

Wild Common Ravens.—In the winter of 1992–1993, I suspended a piece of meat in late evening from a white string attached to a limb 3 m from where at least 50 ravens at any one time were feeding on a cow carcass. Throughout the next three days, the meat remained intact, and I conclude no raven pulled it up. The birds appeared agitated, making alarm calls the first morning for 15 min, and delaying feeding for at least 30 min. Thus, they apparently were fearful of the string.

Two groups of 14 and 13 wild ravens were captured and examined in a 7,000-m^3 aviary in the Maine woods after they had been in captivity for at least two months. In the first group, within 2 h only 1 bird in the 14 came near 1 of the 20 strings, each provided simultaneously with food (no strings were present previously) jumping up and down (i.e. within 1 m) but not touching it. On the second occasion the food was provided (the next day), the same bird again approached, but this time he went directly to the string despite showing hesitancy, and then pulled it up expertly on his first trial. Throughout six days of additional 1-h trials, only 3 of the 14 birds pulled up food. Two additional birds once landed on a perch above a string with food, looked down, and then left without approaching any other string. The nine remaining birds may have examined the food on string, but they never came closer than 3 m to it. Thirteen days after the above tests, the birds again were given food on 20 different strings. The same four birds plus two others now pulled up meat.

In the second group of wild-caught ravens consisting of 13 individuals, 1 bird had pulled up food within 31 min and, within 90 min, 3 more birds pulled up food, for a total of 41 times (strings repeatedly were reprovisioned). No bird ever approached an empty string.

Discussion

Pulling up food attached to string is a behavior that has been described for at least 10 species of birds (Thorpe 1963), and it once was thought to be a demonstration of "insight." Subsequent work examining the ontogeny of the behavior in naive finches and parids, however, showed that it was only acquired in young birds after food was directly attached to the perch. The distance between perch and food was then gradually lengthened a few centimeters at a time.

My study demonstrates that a few (possibly exceptional) individual Common Ravens are able to obtain food suspended on a long string without appearing to go through a lengthy learning process before success is achieved. The successful completion of the task involved reaching down and grasping some string, pulling it up, stepping on the pulled-up loop, releasing the bill from the string, and reaching down again, etc., to repeat the sequence five to eight times.

Fundamentally, there are four ways in which a precise behavioral sequence of numerous steps could be achieved: (1) random chance; (2) programming present already at birth; (3) learning both the sequence and its effect; and (4) insight associated with or without some or all of the above. It is possible, but mathematically highly improbable, that a bird would perform the entire sequence of about four or five different operations into the one correct sequence of 30 or more steps merely by random chance on its very first trial. Genetic programming as an explanation is not a convincing alternative either because there is little or no behavior that corresponds to string pulling in the field. In 12 years of observing Common Ravens in the wild and in captivity on carcasses, I have never seen them pull on one thing to get something else. (They pull on food and, even if pulling on an entrail, for example, they feed on the entrail per se.) Nevertheless, the general capacity to respond to novel situations may be highly adaptive in these birds, allowing them to exploit a great diversity of new situations in diverse environments (Bent 1964).

However, given enough time, it presumably is not difficult to teach a bird a specific sequence of some 30 steps if one starts out at first making the food easy to reach (the string is then gradually lowered), so that motivation is maintained to continue the learning process. The possibility of some learning and some innate behavior in the ravens' performance of accessing food suspended on string is not discounted. However, it also is possible that ravens, on occasion, could have insight into a problem, therefore allowing them to perform this novel sequence of behavioral steps on the first trial. I speculate that the most critical step in the solution to the string-pulling problem was the stepping on pulled-up string. This step could have been achieved by random chance rather than insight. However, insight may have followed so that the random "discovery" could be instantly exploited. Since the birds exhibited correct solutions to five other problems without resorting to or relying on trial-and-error learning suggests that the birds indeed used insight prior to the commitment of overt behavior.

Some of the earlier reports on small finches and tits also invoked "insight" to account for the complex seemingly purposive behavior (Bierens de Haan 1933, Thorpe 1943, 1963), even though the ontogeny of the behavior in the above-listed studies was unknown. However, the purported evidence for insight was later soundly rejected, primarily by Altevogt (1953) and Vince (1958, 1961).

Altevogt (1953) attempted to decipher the ontogeny of the string-pulling behavior in a brood of nine Blue Tits (*Parus caeruleus*) in small experimental cages. He showed that the young birds have a spontaneous tendency to manipulate and pull on anything within reach, and he interpreted the string-pulling response as "a tactile-proprioceptive-stimulus-situation" and, thus naming it, concluded that there is no need to apply terms like insight and understanding to account for the behavior. Nevertheless, Altevogt (1953) never applied food to his strings, and his birds that spontaneously manipulated string never pulled up string with bait, which is the behavior whose ontogeny he sought to investigate. In contrast, my study of captive and wild Common Ravens showed perhaps exaggerated shyness toward suspended string, and the ravens only very reluctantly approached the strings attached to food.

Vince (1961), in contrast to Altevogt, worked with larger sample sizes of 18 European Greenfinches (*Carduelis chloris*) and 16 canaries (*Serinus*). She showed that the full sequence of the behavior was acquired only through a very lengthy process of trial-and-error learning. She was unable to elicit the behavior in adults. In juveniles, she demonstrated it only by first providing the bait directly on the perch, suspending it so that the bird could reach it from the perch, and then gradually lengthening the string throughout the training period. (Such training procedures also were required for laboratory rats to show similar string-pulling behavior [Tolman 1937].)

My series of six different experiments with ravens and string pulling shows a clear departure from all of the previously published literature on other birds. I made no attempt to train the ravens. Instead, the emphasis was on observing the initial behavioral steps as the birds confronted a novel problem. As expected in a response that is not genetically programmed, the birds did not solve the problem quickly and automatically, but when some of them did solve it they showed almost instant mastery of the long series of steps. Without insight, all of these steps would have been relatively arbitrary, and it might have taken much longer to learn the correct sequence.

The few individual ravens that performed the string pulling, as well as novel discrimination tasks, did so without overt trial-and-error learning. The nonperforming individuals presumably could have been taught the same behavior, and then they may have gained the insight of what they were doing during the learning process, which could then accelerate the learning process. Thus, I am not suggesting that insight necessarily is separate from learning. My study did not address whether insight might speed up the learning process. Instead, the issue was whether insight might be possible with either no opportunity, or a minimum (relative to comparable studies) of opportunity to learn. I made a deliberate attempt to experimentally minimize learning in order to better expose possible alternatives.

Although not addressing the issue, my results give no evidence for observational learning of string pulling, as such, but they do not exclude this possibility. For example, the birds might see what is possible. However, the most essential points (precise positioning and pressure of toes relative to string) might not be shown easily. At least one bird in each of three groups quickly and spontaneously pulled up meat attached to a 0.7-m-long string. For these birds, there were no "teachers" present. Some of the subsequent birds that solved the same problem could have copied some aspects of the behavior of the first successful birds. However, in the first group of five birds, the second two birds that pulled up meat used a different technique than the first two. Secondly and more significantly, there was no rush of successes by other birds after one of the group had pulled up bait. Thus, if insight occurred, it was regardless of whether observational learning occurred also; if observational learning occurred, it could not exclude insight.

The second part of my study involved asking what the birds that pulled up food on string "knew." In previous experiments with Budgerigars (*Melopsittacus undulatus*; Dücker and Rensch 1977), birds trained to pull in string (horizontally) with food attached showed no apparent ability to learn to pull on the correct string when two very differently colored strings were crossed. In contrast, one of the Common Ravens in my study solved the problem of picking the correct string at a glance (i.e. picking the unique color that had not been used for food in any previous trial).

It would be difficult to account for all of these results exclusively by random chance, by innate programming, or by learning processes that involve the narrowing of alternative choices that are at first neutral. "Seeing into the situation" before executing the behavior appears to be the most-parsimonious explanation to account for the results. Although not addressed in my study, I expect that the possibility for insight is not arbitrarily distributed and not necessarily transferable to a neutral array of other problems. It seems probable that it is channelled or restricted to quite different ecologically relevant tasks in different animals.

Acknowledgments

Mark Bouton, Dorothy Cheney, Don Griffin, and anonymous reviewers provided valuable comments on earlier drafts of the manuscript. The work was done according to IACUC No. 88-153 procedures and State of Maine Permit No. 75-1743.

Literature Cited

ALTEVOGT, R. 1953. Über das "Schöpfen" einiger Vogelarten. Behavior 6:147-152.

BENT, A. C. 1964. Life histories of north American jays, crows and titmice, part I. U.S. Natl. Mus. Bull. 191.

BIERENS DE HAAN, J. A. 1933. Der Stieglitz als Schöpfer. J. Ornithol. 1:22.

DÜCKER, G., AND B. RENSCH. 1977. The solution of patterned string problems by birds. Behavior 62: 164–173.

GRIFFIN, D. R. 1992. Animal minds. Univ. Chicago Press, Chicago.

HEINRICH, B. 1988. Raven tools use? Condor 90:270–271.

HEINRICH, B. 1989. Raven intelligence. Pages 111–116 *in* Ravens in winter. Summit Books of Simon and Schuster, New York.

HEINRICH, B. 1995. Neophilia and exploration in juvenile Common Ravens, *Corvus corax*. Anim. Behav. 50:695–704.

JANES, S. W. 1976. The apparent use of rocks by a raven in nest defense. Condor 78:409.

KOEHLER, O. 1943. 'Zahl'-versuche an einem Kolkraben und Vergleichversuche an Menschen. Z. Tierpsychol. 5:575–712.

KOEHLER, O. 1951. The ability of birds to count. Bull. Anim. Rehab. 9:41–45.

MALLOY, F. F. 1968. An ingenious hunting behavior in the Common Raven (*Corvus corax*). Ont. Field Biol. 31:77.

MONTEVECCHI, W. A. 1978. Corvids using objects to displace gulls from nests. Condor 80:349.

PEPPERBERG, I. M. 1991. A communicative approach to animal cognition: A study of conceptual abilities of an African Grey Parrot. Pages 153–186 *in* Cognitive ethology (C. A. Risteau, Ed.). Lawrence Erlbaum Associates, Hillsdale, New Jersey.

RISTAU, C. A. 1991. Aspects of the cognitive ethology of an injury-feigning bird, the Piping Plover. Pages 91–126 *in* Cognitive ethology (C. A. Risteau, Ed.). Lawrence Erlbaum Associates, Hillsdale, New Jersey.

THORPE, W. H. 1943. A type of insight learning in birds. Br. Birds 37:29–31.

THORPE, W. H. 1963. Learning and instinct in animals. Methuen and Co, London.

TOLMAN, E. C. 1937. The acquisition of string-pulling by rats—Conditioned response or sign-gestalt? Psychol. Rev. 44:195–211.

VINCE, M. A. 1958. String-pulling in birds. II. Differences related to age in Greenfinches, Chaffinches and canaries. Anim. Behav. 6:53–59.

VINCE, M. A. 1961. "String-pulling" in birds. III. The successful response in Greenfinches and canaries. Behaviour 17:103–129.