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## Bird Tool Use

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### Synonyms

Causal reasoning; Object manipulation; Physical cognition

### Definition

Birds using an unattached object as a means of (better) attaining a goal when their beak or talon is not sufficient.

### Introduction

The ability to use and make tools has played a significant role in our notion of human cognitive evolution ever since Darwin proposed that our minds evolved like our bodies. Tool use was seen as one of our defining features, until Jane Goodall discovered that chimpanzees also made and used a variety of different tools. Although Goodall's observations eventually opened the door to the comparative study of tool use in other primates, otters, rodents, cetaceans, birds, reptiles, fish, amphibians, and even some invertebrates, the idea that nonhuman animals can use and even make tools has been a bitter pill for some to swallow. Tool use has become so entrenched in our idea of what it means to be human, that its very notion is intimately tied to that of human intelligence; tool use has to be a special and highly cognitive behavior. Studies in birds have been at the forefront of unraveling the tangled relationship between tool use and intelligence and revealing some intriguing findings along the way.

### Some Clarifications

Once Goodall's studies had been made public, the idea that chimpanzees habitually used and made tools was rapidly accepted, especially with the publication of photographs in *National Geographic* and ultimately film of the apes in action. Chimpanzees possess hands like ours, they have a similar visual system (and subsequent hand-eye coordination), and they have large brains. Such acceptance was not going to be so easy for birds, which do not have the same obvious manipulative limbs, comparatively small brains and supposedly reduced mental capacities. However, Gavin Hunt published an important paper reporting that New Caledonian crows (NCC) made and used two types of tools: specially shaped leaf tools differing in the number of design steps required to produce them and hooked stick tools (Hunt 1996). Other cases of avian tool use have become apparent: woodpecker finches on the Galapagos Islands removed spines from cactus to use as tools to


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probe into cavities and into bark to retrieve grubs, green heron used “bait” to lure fish to the surface to be more easily taken as food (Higuichi 1988), and Egyptian vultures dropped rocks onto ostrich eggs in order to gain access to the contents inside (Thouless et al. 1989). The most recent definitive survey of animal tool use by Shumaker et al. (2011) reported 35 different categories of avian tool use, including dropping, throwing, baiting, hammering, digging, reaching, inserting, and absorbing, using a variety of natural and manmade objects, across a diverse range of bird groups, but with the highest frequency found in the corvids (crows, jays, magpies, and ravens).

Despite this diversity of tool use in birds, many cases are ambiguous and not from strictly scientific sources. One issue is whether a case of object manipulation should be interpreted as tool use at all. To some degree, this depends on whether the behavior can be attributed as intentional or goal-directed. For example, black eagles and ravens have both been described dropping sticks and stones onto humans from above. This act has been interpreted both from a low-level perspective, as part of a mobbing response towards an intruder, and from a high-level perspective, as an expression of frustration. However, for both interpretations, the mechanics of the act are the same. When comparing dropping a nut onto a rock versus dropping a rock onto a nut, both actions may be performed by the same individual as part of its behavioral repertoire; however, only the latter can be interpreted as tool use (by known criteria). Please note that deriving this interpretation does not assume that one action is more cognitively complex than the other (see later). Dropping a nut when flying may require certain skills in assessing the correct height from which to drop certain sizes of nuts, the cost: benefit ratio of height to number of conspecifics present (so that the contents of nut may be reached before competitors), the speed required to produce an adequate drop to initiate a substantial break in the shell, the appropriate surface on which to launch the nut onto, etc. (Zach 1979). By comparison, dropping a rock onto a nut may only require the application of a simpler rule – “choose the largest rock you can carry, and drop it onto the nut until it breaks”.

Another potential problem with many of the records of avian tool use is the fact that many are anecdotes, reporting only rare or single occurrences, rather than cases that have been the focus of systematic study and experimentation. This does not mean these records have no value, rather they reinforce the view that tool use in birds is rare and except in a few cases, nonhabitual. Of these cases, found only in captivity and which have been studied using empirical methods, not all subjects perform the behaviors, and the actions are only used in a specific context – the procurement of food out of beak reach.

## What Is Tool Use?

Despite sophisticated tool use in a limited number of avian species in captivity (and even fewer examples in the wild), the frequency of tool use is much greater in the apes, both in terms of the diversity of tool types (and functions) and their flexibility. However, the cognition underlying tool use in birds does not appear to be less sophisticated than in apes (and there is good evidence that the physical cognition of crows in some tool-related problems is more sophisticated than demonstrated by apes). Shumaker and colleagues’ (2011) survey of animal tool use documents dozens of examples of tool use in birds, but there are some issues of ambiguity about what may be classified as **true** or **borderline tool use**. A classic illustrative example is the difference between a song thrush repeatedly bashing a snail onto a path or a large stone in order to break the shell and eat the contents. Some might argue that the thrush is using the hard rock surface as a tool (as it cannot open the shell without this external object). However, this is presented typically as borderline tool use as the bird has not detached the rock to be used as a tool that can be carried and manipulated independent of its location. By comparison, Egyptian vultures pick up rocks and drop them onto ostrich eggs in order to break open the shells and eat the contents. In this very similar case, this has been classified as true tool use, as the tool is a detached object (rock) used to procure something (food) ordinarily incapable of being accessed without a tool. Similarly, crows dropping hard-shelled nuts onto roads in Japan or California in order to crack them open on a hard surface (and increase this possibility by dropping them onto roads for cars to drive over) is not an example of tool use, albeit an impressive display of problem-solving (Cristol et al. 1997). This is also a case of borderline tool use, as even using a car to crack open the nuts is not tool use as defined.

The difference between what is viewed as tool use and what is not can be subtle, but it is important when trying to determine whether there are taxa unique tool capabilities and whether these capabilities are dependent on cognition. Perhaps most interestingly, there appear to be brain size differences between avian species that are true tool users and species that only use borderline tools (Lebebvre et al. 2002), with the true tool users having larger (relative) brains and a larger nidopallium. Although the nidopallium has been implicated in complex cognition in birds, whether having a larger nidopallium reflects a cognitive advantage is currently not known.

## Anatomy of a Tool User

Can any bird become a tool user? Are there conditions (morphological, physiological, motivational, ecological) that make tool use more or less likely? The fact that tool use (especially habitual tool use) is rare suggests that a number of preconditions need to be in place in order for tool use to have evolved in one species but not another. This is especially clear when assessing tool use capacities in closely related species. For example, despite there being 45 *Corvus* species, only one, NCCs, habitually make and use tools. A number of other *Corvus*, such as rooks, readily use tools in captivity (Bird and Emery 2009a), but there has never been any reported case of tool use in this species in the wild. Fundamentally, why should a species evolve using a tool over evolving a physical specialization adapted for procuring the same food as acquired through tool use, such as a specialized beak? The beaks of finches on the Galapagos Islands are a classic case of morphological adaptations for foraging. Seed-eating finches have beaks adapted for eating seeds, whereas fruit-eating finches have beaks adapted for eating fruit, etc. Woodpecker finches did not evolve beaks suited to any particular diet but which are suited for manipulating tools. One problem with morphological adaptations is their rigidity. They have evolved for one purpose, which makes them difficult to apply to different problems: a seed-eating beak cannot easily be used for eating fruit and vice versa. It is not clear why woodpecker finches (or indeed NCC) did not evolve specialized beaks, but this fact may have sped up the journey to tool use in these two species. Both species have short, straight beaks that help them hold tools with greater grip strength but also with an increased control of subtle movements. A failure to specialize may have driven these species to generalize their diets (omnivory), which in turn increased opportunities for foraging on a wide variety of plant and animal species, some of which were only accessible with a tool.

These species also possess other morphological adaptations. NCCs, for example, have the widest binocular visual overlap of any bird so far tested (Troscianko et al. 2012). As such, the contralateral eye can see the working end of a stick tool held in the beak on the opposite side. However, Martinho et al. (2014) suggest that because crows prefer to hold the tool in such a way that the tip is on the same side as their preferred eye, they control the tool using monocular vision. It is not clear what advantage either system would provide.

## Tool Use in the Wild: Four Case Studies

Despite a plethora of tool use reports in wild birds, there is not the space to describe them all here. Yet, a brief discussion of some cases of natural and habitual tool use is worthwhile in order to demonstrate the diversity of different uses of objects as tools, and the range of species that use external objects for actions which their bodies alone are incapable. The cases reported here were chosen because they have been the best studied and provide unambiguous evidence for true tool use.

**Egyptian Vultures (*Neophron percnopterus*)**

Egyptian vultures have been observed carrying stones in their talons, carrying them aloft and then either throwing them onto ostrich eggs or picking up rocks in their beaks and carefully dropping them onto eggs. This is an example of drop tool use (Shumaker et al 2011). An experimental study of this behavior found no evidence that this behavior was learned socially, and vultures tended to prefer rounded or egg-shaped stones rather than jagged rocks as missiles (Thouless et al. 1989). It is not clear whether these preferences relate to the stones' efficiency or the subject's previous experience. Studies have yet to be performed concerning the vultures' understanding of properties of the rock (size, shape, weight, height from which the rock needed to be dropped, etc.) or the egg (shell strength, breakage point, etc.).

**Green-Backed Herons (*Ardeola striata*)**

Herons across different continents have been observed using lures, such as insects, bread, twigs, and feathers held in the tip of the bill, as bait for fish, which take the bait, and then subsequently are caught by the heron holding the bait (Ruxton and Hansell 2011). This is an example of bait tool use (Shumaker et al. 2011). Seven out of 12 species of herons catch fish this way, displaying either active or passive bait-fishing. Active bait-fishing uses a lure either dropped and left or held in the bill; as such it is a supposed demonstration of goal-directed behavior. Passive bait-fishing are cases when a heron benefits from a fisherman dropping a lure or one naturally floating in the water, and then taking the fish attracted to that lure. It is not clear how active bait-fishing developed, perhaps after forming a causal link between observing a fish take a bait and intentionally using a bait to catch a fish. Although individual differences in this behavior have been studied, subsequently finding that not all individuals perform this behavior or they differ in the level of their skill (and subsequently success), little is known about the underlying cognitive abilities involved (Higuchi 1988).

**Woodpecker Finches (*Cactospiza pallida*)**

Woodpecker finches are found exclusively on the Galapagos Islands, primarily Santa Cruz. They use twigs or cactus spines (either found or naturally detached) which they hold in their beaks to poke into bark to dislodge their prey, wood-boring beetle larvae. This is an example of probing tool use (Shumaker et al. 2011). In many cases, the finches modify these tools, shortening them so they are easier to handle. This form of tool use seems to be innate, as juvenile finches do not need to observe an adult before they use their first tool (Tebbich et al. 2001). However, whether finches use a tool depends on where they are located on Santa Cruz and the season. Tool use only occurs in the arid zone and only in the dry season. In the wet season, the grubs move to the surface and so can easily be accessed without tools, whereas in the dry season, the grubs bury themselves deep under tree bark (Tebbich et al. 2002). Finches acquire approximately 50 % of their total food from prey captured using tools in the dry season in the arid zone.

**New Caledonian Crows (*Corvus moneduloides*)**

Like woodpecker finches, NCCs appear to fill in the ecological niche usually occupied by woodpeckers on the mainland. Huge grubs are found under tree bark or buried within leaf litter that are unreachable without a tool to prize them out. NCCs use three types of tools: probing tools of different shapes made from the tough, barbed leafs of *Pandanus* plants and sticks either with or without hooked ends (Hunt 1996). Both tools are created using a multistep process (see "▶ Tool Manufacture"). Both types of tool utilize a hook, either natural barbs located on one side of the leaf or a hook that is created and then fashioned by removing the stick from the original tree. These hooks function in levering a grub from out of its otherwise inaccessible hiding place. There are four main types of leaf tools: wide, narrow, single step, and multi-step, with the narrow and multi-step the more complex to make. These different types are not found distributed equally across

New Caledonia, suggesting that the different tool types are either environmentally constrained in some way (e.g., by the amount or quality of the raw material), which is unlikely as they are made from the same plant, or individuals have adapted an original design into innovative new designs that have been copied and taken elsewhere, which has been proposed as a case of cumulative cultural evolution (a trait that has been suggested to be uniquely human). This process could have been the result of crows learning a new design from watching other crows or possibly extrapolating from the leaf counterparts left after a tool is made, then moving to a different population (perhaps after leaving the family) and the new design spreading through the new population.

## Tool Use in Captivity: Three Case Studies

Despite the limited number of birds that regularly use tools in the wild, there are other birds that are capable of using objects as tools in captivity. Why? Most birds are beautifully adapted to gaining and processing food with bodily adornments evolved through millions of years, namely beaks (and feet; parrots). Although tool use may provide a cognitive constraint on whether tool use evolves in one species, but not another, we think this is unlikely in closely related species, especially those for which we find evidence for similar cognitive abilities in tasks not dependent on using tools (Teschke et al. 2011). It is more likely that ecological and/or morphological constraints have driven one species to use a tool and not another. Indeed, there is accumulating evidence that tool users do not outperform closely related species on tool-related or other cognitive tasks (see below).

### Goffin's Cockatoos (*Cacatua goffini*)

Goffin's cockatoos are typically found in Indonesia but are a popular pet. They have not been reported to use tools in the wild, although little field work has been performed on this species, due to difficulties in tracking them in the dense forests where they live (a pattern seen for many Psittaciformes). However, a single individual, Figaro, housed in a large captive group in Vienna, Austria, was discovered to have taken long elongated splinters from his wooden aviary to rake in an out of reach cashew nut (Auersperg et al. 2012). Figaro made the tool shorter, presumably so that it was easier to handle. Parrots are relatively rare tool users, probably because the types of foods they naturally encounter and subsequently incorporate into their diet – despite being tough skinned or possessing shells – can be processed using a combination of very tough beaks that shear and smash and gripping feet that hold such items steady when being manipulated with the beak. In this current example, such anatomical adaptations would have been useless for the simpler act of retrieving an out of reach object.

### Kea (*Nestor notabalis*)

Kea are alpine parrots living in the mountains of the Southern Island of New Zealand. Like many island birds, they have quickly taken over niches typically occupied by other animals, in the case of kea, carrion birds (although like other carrion feeders, they are omnivorous). Compared to the beak of a cockatoo, which is ideal for crushing and peeling off the tough shells of nuts and the skin of hard fruit, keas beaks are curved and adapted to tearing flesh. This they do, even on live sheep, to the consternation of farmers. As with cockatoos, there may be little reason for kea to use tools in the wild, but in captivity they can use sticks as tools (Auersperg et al. 2011). Numerous cognitive tests have revealed that kea solve novel problems, especially when learning from others (Huber and Gajdon 2006).

### Rooks (*Corvus frugilegus*)

Rooks are corvids that have a wide distribution across Europe and Asia as well as an introduced population in New Zealand. Their behavior has been studied quite extensively, especially their breeding biology and social interactions, yet there are no reports of them using tools. This might be because they have rather long beaks compared to other crows, which are used for digging deep into soil for earthworms as well as creating elaborate cache sites. Such an anatomical adaptation leaves little requirement for a tool. It is a different story for captive rooks who have demonstrated the flexible use and understanding of tools, such as stones and sticks in multiple problem-solving contexts (Seed et al. 2006; Bird and Emery 2009a, 2009b). For example, when presented with a puzzle-box in which a collapsible platform held up by a magnet can be triggered to release the treat it is holding up, it took only five trials for a number of rooks to learn the affordances of this task (where stones could be accidentally knocked into the puzzle-box, and therefore demonstrate how it works). The birds rapidly applied this knowledge to using the best tool for a specific function, such as dropping a large stone into a wide tube or a small or thin stone into a narrow tube. In a different task, in which a small bucket containing food was located at the bottom of a tube, rooks were provided with wooden V-shaped hooks, either functional (the V was turned upright) or nonfunctional (the V pointed downwards). Rooks spontaneously chose the functional hook to retrieve the bucket and get the reward (Bird and Emery 2009a).

## Is Nest-Building an Example of Tool Use?

Another consideration that is almost unique to birds is the question of whether nest-building is a specialized form of tool use. Until recently, this would not have been seen as an important question, as the act of nest-building was seen as a purely instinctual behavior, under genetic and hormonal control, and little within the realms of comparative cognitive science (Hansell 2000). However, recently the psychological processes underlying nest-building have become the focus of intense scrutiny (Breen et al. 2016), revealing hitherto unheard of roles for learning and physical cognition that lend themselves to a more complex interpretation of this ubiquitous behavior. If we apply the definition of tool use to nest-building, mechanistically they are very similar. Indeed, in some respects, nest-building is a more complex mechanical process than all known forms of avian tool use (Breen et al. 2016). However, the fact that a behavior appears complex does not mean that it is complex. So it is with tool use, so it (probably) is with nest-building. However, the very same actions that are essential for selecting an appropriate tool and using it correctly within a specific context are basically the same processes for both tool use and nest-building. This area is in need of further research.

## Tool Use and the Avian Brain

Tool use is dependent on a wide suite of abilities, such as motor skill learning, beak(hand)–eye coordination, and causal reasoning. This is amplified when considering a taxon which does not have hands, and has to both hold and manipulate an object using the beak (and very occasionally the feet), that is located close to their eyes. As such, tool use should also be dependent on a highly evolved brain. Although there are no studies of the neural basis of tool use in birds, a number of correlates between the propensity to use and make tools and some measure of the brain (absolute and relative size of the whole brain, pallium or subdivisions of the pallium, size of the cerebellum or its subdivisions, or even specialized neurons) have been reported. For example, there is a clear relationship between brain (and nidopallium) size and the frequency of reported cases of true tool use (Lefebvre et al. 2002), which is more prevalent in corvids and parrots (which tend to have larger brains anyway). Within corvids, NCCs have larger association areas, such as the nidopallium and mesopallium than other corvids (Melhorn et al. 2010), but it is not clear what this size increase actually means with regard to cognition.

Even if we accept that cognition plays some role in tool use (however, see below), we are less likely to argue that it is not a complex manual skill. As such, we might expect that the area of the brain most closely associated with manual dexterity and motor learning, the cerebellum, should be different in tool users compared to nontool users. Indeed, tool-using birds have a more significantly folded cerebellum (i.e., increased foliation) than nontool using birds (Iwaniuk et al. 2009). Again, how this relates to the production of a complex skill is unknown.

## Is Tool Use Intelligent?

Despite the ubiquity of tool use across the animal kingdom, to the public, the ability to use a tool is synonymous with intelligence: humans can use tools, so any creature that can also use a tool must be intelligent. Is there any experimental evidence to support this claim? Comparative psychologists have designed a number of clever tasks in an attempt to reveal what an animal may understand about the property of an object that allows it to be a functional tool in one context but not in another. Tasks have also been designed to establish whether animals understand the concept of causality; that their actions in using a tool have specific consequences (effects). Perhaps surprisingly, animals that are highly proficient tool users in the wild are no better at using tools appropriately in a problem-solving context in captivity. For example, a classic test of causal reasoning is the trap tube task. A subject is presented with a transparent tube, with food located at its center. On the underside of the tube is a trap into which the food will fall if moved into it. To remove the food from the tube, the subject has to insert a tool and use it to maneuver the food out of the tube while avoiding the trap. Chimpanzees, capuchins, and woodpecker finches eventually learn after dozens of trials to produce the correct behavior (insert a stick into the correct side) and remove the treat (Emery and Clayton 2009). However, when the tube is inverted, so the trap no longer presents an obstacle to removing the treat, subjects perseverate on poking the tool into the side in which they had previously been successful. Some commentators have stated that this suggests these subjects do not understand the task, despite the fact that the rational choice is to continue what has been previously been successful. An adaptation of this task, with the addition of a nonfunctional trap in which food can either fall through or pass over a solid base (two-trap-tube task), was also adapted for use by non-tool-using species, such as rooks, by presenting a tool already inserted into the tube, so all the subject had to do was pull from the correct side to avoid the functional trap. Rooks were capable of solving both adaptations more rapidly than chimpanzees could solve the original task, transferring to the alternate version, and one bird also solved a version in which possible learning cues were removed, suggesting causal reasoning (Seed et al. 2006). NCCs tested on a similar version performed like rooks and also transferred to a novel trap table task (Taylor et al. 2009), whereas there was little evidence that woodpecker finches could solve this task, with the exception of one bird (Teschke and Tebbich 2011).

In order to determine whether tool users possess an advantage over nontool users in terms of cognition, one needs to design a task that tests for physical reasoning but which is not dependent on the animal performing the task being a tool user. The two-trap tube task asks the subject nothing more than the ability to pull a stick; the cognitive requirements are dependent on the ability to discriminate between different courses of action and their consequences. A different task designed for tool users and nontool users alike is the collapsible platform task (Bird and Emery 2009a). A perspex box with a vertical tube on top contains a platform inside held upright with a magnet. Dropping an object of sufficient weight/size/shape into the tube dislodges the platform and releases a reward to the subject. By adjusting the width of the tube and the strength of the magnet, a subject can be tested for their understanding of what constitutes a functional tool. For example, a large stone can be placed into a wide tube but not a narrow tube or a small stone may be too light to displace a stronger magnet or a long stone may fit inside a narrow tube, but only if oriented lengthways. Bird and Emery (2009a) tested rooks on a series of these problems after initially training them to place stones into the tube on top of the test box (using shaping and rapid learned). The rooks performed successfully on the first or second trial of every problem they were presented, including transferring to sticks of different sizes and shapes, as well as presenting cases where on a previous trial they had been successful (i.e., the tool was functional), whereas on the next trial the context changed, and the same tool was no longer functional. The rooks were also successful on sequential tool use tasks, in which they had to choose one tool in order to gain access to a second tool that could be used to access food.

A different task in which subjects were required to drop stones into a tube was designed around an Aesop's Fable called "The Crow and the Pitcher" in which a thirsty crow spies a pitcher of water, but the level of the water is too low for the crow to drink. The crow hits upon the idea to add stones to the pitcher, so raising the water to a high enough level to drink. Bird and Emery (2009b) designed a comparable task with a tasty treat floating on the surface of the water. Rooks (with experience of the collapsible platform task) started adding stones into the water-filled tube until they could reach the worm on the surface. They tended to choose the largest stones and rapidly learned to avoid placing stones into a sand-filled tube when presented alongside a water-filled tube. Additional studies using the Aesop's Fable task have been performed on other non-tool-using birds such as Eurasian jays (Cheke et al. 2011) as well as tool-using New Caledonian crows (Taylor et al. 2011; Logan et al. Taylor 2014) with a number of very clever variants designed to determine whether the birds' performance was due to instrumental conditioning, causal reasoning, or even insight. Importantly, there does not appear to be any difference between the performance of tool-using crows and other non-tool-using corvids.

## Conclusion

Birds as a group are as proficient tool users as primates, but their interest in tools tends to be restricted to the acquisition of food. By comparison, primate tool use is more diversified across different technical and social functions. It is not yet clear what role tool use may have played in the evolution of avian cognition, as so few species regularly use tools in the wild, and the performance of tool-using and non-tool-using species on tests of physical cognition does not appear to differ. It is suggested that tool use in birds may have evolved as the consequence of morphological adaptations and environmental factors, rather than some increase in brain power leading to cognitive specializations.

## Cross-References


- ▶ Brain Size and Intelligence
- ▶ Causal Reasoning
- ▶ Cephalopod Tool Use
- ▶ Confounding Use of Tools on Physical Tasks
- ▶ Convergent Evolution of Intelligence
- ▶ Convergent Evolution of Intelligence Between Corvids and Primates
- ▶ Corvids
- ▶ Evolution of Tool Use
- ▶ Fish, Amphibian, and Reptile Tool Use
- ▶ Innate and Learned Tool Use
- ▶ Innovation and Creativity
- ▶ Insight
- ▶ Meta-Tool
- ▶ Nonhuman Tool Use
- ▶ Primate Tool Use
- ▶ Proto-Tool
- ▶ Role of Experience in Tool Use
- ▶ Sequential Tool Use
- ▶ Stick Tools for Foraging
- ▶ Tool Manufacture
- ▶ Tool Use
- ▶ Tool Use in Captivity
- ▶ What Makes a Tool


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