

## Something to Crow About: Birds with Tools

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### Psychology

Locals in New Caledonia tell of crows using tools made from leaves. Crows were introduced to the island around the inception of European colonialization *ca. 1850* (Hunt & Gray, 2003). New Caledonians have embraced the stories about their crows using tools. Their national postage stamps feature a crow holding a leaf tool in its beak. New Caledonian crows (NCCs) manufacture a distinct variety of tools, depending on their functional demands. Indeed, human folklore attributes intelligence and cleverness to crows and recounts of their ability to understand cause and effect relations (Aesop & Rackham, 1975). In *The Crow and the Pitcher*, a thirsty crow finds a pitcher with water at the bottom. However, the jug is too heavy to overturn, and the mouth of the pitcher is too narrow to reach inside and drink. The crow picks up pebbles and drops them within the pitcher. Doing this causes the water to rise, and the thirsty crow satiates its thirst.

Tools differ from materials. One can imagine a nest as a tool created by a bird for the purpose of sleeping. However, to make its nest the bird uses their beaks or claws when manipulating stick materials. The nest is not the tool which the bird uses to sleep, but the material which the bird manipulates. A tool is a manufactured functional object. Tool use can be defined by "the use of an external object as a functional extension of a mouth or beak, hand or claw, which extends the physical influence of the animal in the attainment of an immediate goal" (Goodall, 1970; Kamil & Jones, 1973). True tools are neither beaks nor claws.

The evolution of tool use in *Homo Sapiens* reveals important aspects about the development of higher-order cognition. Some point to tool use as a prominent advantage that humans utilized to compete with rival species. It remains unclear if tool use by early humans caused them to develop

larger brains, or rather, if larger brains led to the development of tool use. Tool use has only been achieved by two distinct organizations of brain architecture: one in mammals, the other in birds. Researchers continued to equivocate the intelligence of crows with that of the great apes. Corvids, members of the crow family, possess brains which are relatively larger in relation to their body weight than compared to most other species. Specifically, the brains of NCCs tend to contain larger mesopalliums, pallidostriatal complexes, septums, and tegmentums (Cabrera- Álvarez & Clayton, 2020) compared to those of other birds. The pallium makes up about 75% of the total brain volume of adult birds (Jarvis et al., 2005). The neuroarchitecture of the brain which underlies tool using behavior matters less than the specific subdivisions and connections between neural substrates.

Tool use was significant in the development of higher-order cognitive faculties in early humans. Research which investigates tool use in birds can test the functions, methods, and motivations for tool use which members of *Aves* has selected for in their evolutionary histories. Several orders of *Aves* contain tool-using birds: *Accipitriformes* (diurnal raptors), *Ciconiformes* (herons, storks), *Psittaciformes* (parrots, macaws), and *Passeriformes* (perching songbirds). Hiroyoshi (1985, 1986) describes how herons learn to use bait such as sticks, twigs, grass, leaves, and insects to lure fish within their striking distance. Captive macaws place sticks within their beaks to break open nuts. Borsori and Ottoni (2003) describe their innate tendencies to place tools and food together within their beaks while feeding. Woodpecker finches hold stick tools within their beaks to probe into dead wood for beetles (Tebbich, Taborsky, Fessl, & Blomqvist, 2001). Studies of tool use across psittacopasserae, accipitriformes, and ciconiformes demonstrate that NCCs behave uniquely with physical materials. They have learned to fashion leaf tools as an adaptive foraging technique.

When crafting tools, NCCs represent functional and social worlds. Corvids behave as if they perceive the representations of the knowledge states *and* preferences of multiple observers at a time.

They seem to employ these representations in guiding their decisions. For instance, nutcrackers which hear the noises of a nearby conspecific are more likely to protect their caches by recaching or by engaging in behavior which misleads their conspecifics. By recaching food items after they believe conspecifics are aware of the location, they behave as if they understand the intentions of others (i.e., that others want to steal their hidden food). NCCs behave as if they understand the causal effects of their tool use. This behavior offers support for the notion that they possess a “folk physics.”

Observations in New Caledonia and research at Oxford suggest that NCCs possess a rudimentary form of causal reasoning. NCCs demonstrate flexibility in their tool use in that they modify novel materials into functional shapes. Keefner’s (2016) research indicates that crows hide their food differently when in the presence of a visual or auditory conspecific. Crows are kleptoparasitic, meaning that some will steal each other’s food. It is advantageous that crows generate representations of conspecifics and their mental states. They hide food when they know another crow is watching them. Emery and Clayton (2004) propose that natural corvid caching behavior reveals NCC prospection, given that the prior hiding and subsequent retrieval of food items necessitates a perception of temporality. Temporality grounds cause and effect, as a sequence.

### **NCC Tool Use in the Wild**

Most tool-using birds can be found within *Corvidae*. NCCs manufacture and utilize sticks, hooks, and stepped-leaf tools which they cut from the leaves of the *Pandanus* plant. They use leaf tools to pry *cerambycidae* bugs out of the dead wood of the *Aleutirites moluccanus* tree (Hunt, 2000). Observations of wild NCC foraging behavior and experiments with captive NCCs support the notion that NCCs fashion tools out of physical materials to meet a functional foraging demand. Wild NCCs create tools to extract larvae from trees. They prefer certain shapes and methods of holding their tools. Even in captivity, NCCs can learn about tools. They spontaneously manufacture and modify tools

without any social input from wild birds, suggesting that tool use may be innate in NCCs. Evolution has selected for the ability of crows to understand cause and effect relationships.

The notion that *Corvidae* understand cause and effect are supported by their goal-directed use of tools, which they generally fashion from the leaves of the *pandanus* plants. Observations of the tools NCCs create describe the physical material, shape, diameter, length, and manipulation of manufactured objects. Hunt and Gray (2002; 2003; 2004a; 2004b) collected 5550 NCC tools from across New Caledonia, in a range of altitudes. Next, they traced the outlines of the tools. Hunt and Gray found two types of tools made by NCCs: stick tools (made from sticks, twigs, vines, and bamboo), and leaf tools (made from the *pandanus* plant). Tracings of stick tools and leaf tools indicate three general tool shapes: wide, narrow, and stepped.

Stepped tools require the most effort to manufacture. They require a ‘cut and rip’ technique to manufacture (Hunt, 2000). The style of tools differed across the island. Narrow tools were only made southeast of Grand Terre. Wide-stepped tools were made most frequently. Hunt (2000) observed few NCCs which show a complete lack of experience with tools. Although the manufacture of tools such as hooks occurs late in human history (Hunt, 2000), NCCs can already manufacture hooks. Hunt and Gray (2004) report a four-stage progression of hook manufacture. Crows first select a fork in the branch, then break the side twig off, and break the remaining twig below the junction. After removing the leaves, they have successfully sculpted a clean hook. NCCs tend to manufacture their tools on the left edges of *pandanus* leaves. They prefer to hold tools beneath their left eye.

Critically, Hunt and Gray (2002; 2003; 2004a; 2004b) observe how NCCs manufacture tools *before* using them. This provides convincing evidence for the goal-directed nature of their tool use. Tool use provides NCCs functional advantages. Before crows, only humans were thought to possess the representational, sequential, and goal-driven ability of tool manufacture and modification. The

shared use of *pandanus* tools by wild NCCs, the similarity of ‘cut and rip’ methods, and the convergence of tool designs among the population suggest a common origin among tool-using NCCs.

### **Tool Use by Captive NCCs**

Kacelnik’s research laboratory at Oxford investigates the manufacture of complex tools by captive NCCs. Their studies of NCC tool manufacture and tool selection under controlled laboratory settings offer additional support for the notion that crows may understand cause and effect relations. Weir, Chappell, and Kacelnik (2000) describe how a captive female crow named Betty bends a wire into a hook to lift a bucket out of a tube. When she lifts the bucket, she receives a food reward. In nine out of ten trials, Betty bent a wire into a hook and lifted the bucket out. Betty had seen and used premade wire hooks before, but she never bent a wire herself before this test. In Betty’s first trial, she attempted to lift the bucket out of the tube with an unbent wire. She failed on the first trial. On the remaining nine trials, Betty bent the wire into a hook and lifted the bucket from the tube. Although Betty lacked experience modifying wire into hooks, she spontaneously and consistently bent novel materials into hook-shaped tools to solve a task.

In a second experiment, Weir and Kacelnik (2006) investigated whether Betty could unbend a wire in the same bucket-tube test. After six months without tool use, the research team supplied her with a novel tool material. Though she lacked experience unbending tools, Betty adapted quickly to the new material and had a high level of success unbending tools. Given her ability to modify tools in new ways depending on her needs, and her performance on trial one, Weir and Kacelnik concluded that Betty likely understood aspects of the bucket-tube task and combined them with trial-and-error learning, guided by reinforcement. They believed that Betty understood the causal relationship between her tool modification and its resulting function: to pull the bucket upwards.

To see if NCCs inherit characteristics that support tool making, Kenward, Weir, Rutz, and

Kacelnik (2005) investigate spontaneous tool manufacture in four additional naïve juvenile NCCs. Human handlers demonstrated to two of the birds how to extract food by using twig tools. A second group of two untutored group of NCCs never watched humans demonstrate how to use twig tools. However, all four of them developed the ability to make twig tools within the same developmental time frame. In a second experiment, experimenters mounted *pandanus* plants in the birds' enclosure. One bird, Corbeau, manufactured a straight tool from a *pandanus* leaf using the cut-tear-cut method in the very first day the plants were introduced. The similar rates of tutored and untutored naïve juvenile NCCs' tool manufacturing and Corbeau's immediate intention to craft a *pandanus* tool offer support for the notion that the ability to make and use tools is at least in part innate in NCCs.

To examine whether NCCs actively search for their preferred tool, Chappell and Kacelnik (2004) offered two NCCs sticks of three different diameters. The tool diameter task involves a food cup placed behind a transparent wall with a hole of variable width. A tool inserted through the hole can push against the food cup and it will fall down a chute. When the cup falls, the NCC receives the reward. In "none-loose" trials, all three sticks (thinnest, thin enough, too thick) are tied into a bundle. In "one loose" trial types, one stick remains on the table while the other two are tied in a bundle. The birds demonstrated a preference for the thinnest tool, regardless of the width of the hole.

In experiment two, Chappell and Kacelnik (2004) presented the birds with an oak (*Quercus robur*) branch and tested how NCCs which manufactured their own tools would perform on the tool diameter task. The two NCCs approached the hole and inspected it *before* manufacturing tools from the oak branches. The two crows obtained food successively on the first use with their tool in 27/30 trials. The two NCCs manufactured tools according to the width of the hole; while the NCCs could always manufacture a 'thinnest' tool, they did not. Instead, the NCCs often manufactured branch tools which were 'just right' to fit in the width of the hole. The tool diameter task, tool length task, and trap

tube test have shed light on the tool preferences of NCCs.

One can infer that NCCs dynamically select and manufacture tools based on the needs of a task. NCCs have evolved to minimize the energy expenditure incurred during tool selection and manufacture. In Chappell and Kacelnik's (2000) tool length task NCCs were offered a selection among a set of stick tools with a variety of lengths. Their performance on a novel food-extraction test was measured: food was placed at varying distances within the transparent pipe. A second experiment even tested NCCs choice of tool length when the transparent pipe was outside of their visual field. Chappell and Kacelnik defined their choice of tool as the first stick to be inserted into the pipe. Most NCCs started these trials by approaching and gazing into the transparent tube. During testing, the NCCs approached the tools *after* analyzing the pipe. They manipulated the lengths of their tools by using their beak to pinch the tool closer to the functional side in a lateral manner. The birds demonstrated a strong preference for the longest tool in general even though they could have selected shorter sticks and retrieved the food if they were willing to hold the tool by the tip and stick their head within the tube. Furthermore, as food was placed further within the tube, NCCs tended to manufacture longer and longer sticks. This indicates that NCCs considered the functional demands of their task and did so *before* creating tools to help them achieve their goal. The energy an NCC expends in making and transporting a tool is founded in the functional demands of the task which they aim to solve; they neither waste their time nor energy in making a tool without a motive.

After Hunt, Rutledge, and Gray (2006) learned about Kacelnik's success with Betty in the tool diameter task and tool length task, they tested which cognitive strategies wild NCCs use while solving a similar task. They designed a novel tool length task for wild NCCs foraging in the island, where they used a transparent feeding box. This allowed them to vary the depth of the hole easily while revealing the extraction methods of the crows. Researchers noted the persistence with which

NCCs extracted larvae from the transparent feeding box. The pair of crows tended to make longer tools as trials progressed. When crafting tools, they largely ignored twigs scattered around the transparent box in favor of nearby *pandanus* leaves. These wild NCCs used a two-stage heuristic strategy to solve this test. To manufacture an extractive foraging tool, NCCs first applied a default behavior to a tool problem. They only adapted a new problem-solving technique if their initial default behavior failed. The consistent use of *pandanus* tools implies that the pair of NCCs use *pandanus* tools in foraging. After trials where their tools were too short, they fashioned a longer tool in the next trial.

The selection, manufacture, and modification of tools requires attention. It requires an inclination towards the physical properties of tools. To investigate whether wild NCCs attend to the functional properties of hook tools, St. Clair and Rutz (2013) drilled several holes downward into a food log and placed meat inside. Then, they offered wild NCCs with hooked tools, placed in one of three orientations: flat on a presentation log, pointed hook-end downward into the presentation log, or sticking hook-end upwards out of the presentation log. After retrieving the tool from the presentation log, NCCs transported the tools to the food log to use them. Birds in the hook-end-up condition tended to reorient the tool so that the functional hook end faced downwards before attempting to extract meat from the log. Thus, without trial-and-error learning, the tool-using wild NCCs attended to the functional, causal hook property of the tools.

### **A Comparison of Tool Use Behavior within *Aves***

A comparison of tool use between crows and other birds who cache food items reveals the folk physics which *Corvidae* possess. Kenward et al. (2010) compared the development of precursor behaviors in crows and ravens to better understand the origin of *Corvidae* tool use. Precursor behaviors are defined as when a bird holds an object in its beak/foot and places it against another



object/substrate. In precursor behaviors, birds initiate nonfunctional object play. Kenward et al. raised crows and ravens with multiple crevices and substrates present. Each of the birds developed tool use at similar rates. Some NCCs were tutored in tool use, which involved poking a stick into a crevice/substrate while the birds watched. These tutored NCCs produce more tools than the untutored NCCs, as well as the ravens. Ravens are caching corvids which do not use tools in the wild, but they develop tool-oriented behaviors at a similar rate to NCCs. Thus, Kenward et al. (2010) inferred that tool use and food caching in *Corvidae* develop from the same precursor behaviors.

The tube trap tests animals for causal understanding. A food item is placed within a horizontal transparent tube, and a rook (*C. frugilegus*) can pull a stick placed within the tube from either direction to pry the food out. However, sometimes the bird must navigate the food item around a hole 'trap' within the tube: depending on which direction the rook pulls the stick from, the food will be pulled either into the hole trap or towards the rook's hopeful beak. Animals are thought to demonstrate an understanding of causality when they do not choose to avoid a nonfunctional trap (Seed, Tebbich, & Emery 2006). Eight naïve juvenile rooks transferred their learning when a single-hole trap tube task was flipped. Next, rooks were tested in modified tube traps. In a tube with two holes, investigators sometimes filled one of the holes so that the food could slide over it. Investigators could also open the bottom of the hole so that food pushed in would fall free. All rooks transferred their learning in a modified trap-tube test. One rook, Guillem, passed two more transfer tests. The transfer of learning by naïve juvenile rooks in a causal understanding test reflects a more general cognitive ability within *Corvidae* (Tebich, Seed, & Emery, 2007) based on their ecology. The generalist nature of corvid foraging, corvid sociality, and the highest rate of feeding innovation of any family of birds contribute to these complex behaviors.

Teschke et al. (2013) compared the performance of tool-using passerines NCCs and *C. pallida*

with non-tool using carrion crows and small tree finches. Both species of birds were offered a choice between two canes. Food was only ever contained within one of the hooked ends. After the initial task, four transfer tasks were created. Both NCCs and carrion crows performed equally well on the learning tasks. However, no carrion crows solved the cane task. Most NCCs and all woodpecker finches passed the initial learning task, and NCCs performed similarly to woodpecker finches in later trials. The difference in performance between crows but not between finches in the cane task led Teschke et al. (2013) to conclude that cognitive adaptations arise more frequently in species such as NCCs which use tools in more complex ways. The behavior of non-NCC *Corvidae* in the trap-tube test and the cane task highlight the learning abilities of NCCs in relation to other *Corvidae* and support the notion that a group of tool-using traits is shared among *Corvidae*.

Research by Tebbich and Bshary (2004) and Tebbich et al. (2001) outlines the cognitive abilities and social learning mechanisms related to *C. pallida* tool use. *C. pallida* uses tools most (Tebich & Bshary, 2004). They use trial and error learning in trap-tube tests, tool-length tasks, and tool modification tasks. One out of six woodpecker finches solved the trap-tube task, and three out of five selected a tool of a sufficient length (2004). Tebbich et al. (2001) found that juvenile woodpecker finches were more likely to follow tool-using adult models rather than choosing to observe their own tool-using parents; two juveniles even kept snatching sticks from the beaks of model finches! Tebbich et al. concluded that although all juveniles demonstrated similar precursor behaviors, the development of their tool use did not depend wholly on social learning mechanisms.

One social learning mechanism, stimulus enhancement, promoted the learning of a physical task in nine hand-raised ravens. This procedure presented animals with two viable options to complete the task: in Fritz' and Kotrschal's (1999) study, ravens could either choose to pull a string to a box door to retrieve food inside or they could lever their beak within the crevice of the door to push the door

open. In both cases the raven could open the box to retrieve food. Fritz and Kotrschal (1999) utilized this two-action box test to explore the significance of social learning in dyads of food-caching corvids, *C. corax*. By designating one bird a model and the other an observer, they evaluated how observer birds opened the box after witnessing a control retrieve food. All control ravens levered the box open, and observer ravens were more likely to pull the flap on the box to open it in subsequent trials. Given that ravens were more likely to pull the flap after watching a conspecific solve the two-action procedure with another method, observer ravens must explore the flap more than controls due to the increased salience of the stimulus caused by the conspecific's interaction.

### **Discussion**

If we imagine a simple substance whose structure makes it think, sense, and have perceptions, we could imagine it enlarged and enter it as one does a mill (Leibniz, 1686). Inside this mill we can look around and watch the mechanical gears spin, but we can never point to anything to explain its perceptions. Some error necessarily pervades the sensations and perceptions out of which crows fashion their social, functional worlds. Instead of romanticizing corvid cognition, one must prefer the most simple, logical explanations for their tool use behavior. Likewise, Bluff et al. (2007) cautions the cognitive psychologist against "ascribing general cognitive abilities to the whole *Corvidae* family based on the abilities of individual species". To wonder what it is like to be a crow proves as futile as proving whether corvids even perceive the same worlds as each other.

NCC tool-using abilities stem from their ecological adaptations. They are an invasive species in New Caledonia, and their foraging strategies promote their use of novel physical materials to aid in foraging behaviors. Nevertheless, NCCs associate functional properties with their representation of the *pandanus* plant. This is likely due to their innate nature as generalist foragers, their larger brains, and their adaptability within a novel ecosystem. Since humans and crows independently evolved tool

use during different points in their phylogenetic history, we may conclude that evolution selects for the ability of a species to interpret the causal law and that understanding this causal law improves the fitness of the being which represents it. We can infer from their tool-using behaviors that they represent more complex worlds than do other species of birds. In nature, causality presents itself as strict causes, stimuli, and motives (Schopenhauer, 1813). Strict causes are those which change in the inorganic world, like gravity and chemistry. Stimuli are those causes which directly affect substances. Motives are consciously performed actions. Corvids represent the motives of other substances. They behave differently around conspecifics which they perceive as helpful or harmful. They represent certain goals towards which they aim. They demonstrate a receptibility to forms of causality. They represent a world ripe with functional, modifiable substances. NCCs possess a necessary and sufficient reason to represent themselves as causal beings.

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