Tools for thought or thoughts for tools?

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Bird and Emery report in this issue of PNAS (1) that rooks (*Corvus frugilegus*), corvids that do not habitually use tools in the wild, appear to possess tool-related capabilities hitherto known only in their tool-using relatives, the New Caledonian crows (*Corvus moneduloides*) (2–5). Their findings are striking in more than one respect, but it is of particular interest to evaluate their significance for theories about the influence of tool use in the evolution of intelligence, for recent arguments against the value of evolutionary thinking in relation to cognition (6) and for that old nugget, the use of metabehavioral concepts such as insight as causal explanations for behavior.

Tool Use and Intelligence

The evolution of tool use and its relation to intelligence have for a long time been assumed to be related topics. Because humans are outstanding among animal species in their general intelligence and in their sophistication as users and makers of tools, it is not surprising that tool use is often invoked among the candidate traits (together with language, cumulative culture, and excessive prosociality) that may have promoted the development of human intellectual uniqueness. A simplified version of the argument could run like this: something in early hominids' ecology led them to rely heavily on tools, and this created a special niche, within which selective forces favored heritable traits that conferred an advantage in tool-oriented competence. The latter, in turn, depends on the ability to predict objects' interactions by means of sophisticated folk physics. The development of tool-dedicated abilities could secondarily enhance the spread of traits associated with abstract reasoning, and the associated advantages of being able to transfer skills to relatives and members of one's band would in time promote the evolution of language and cumulative technological culture. In an opposite direction of causation stand hypotheses that see tool competence as derivative of general-purpose intelligence. For instance, if some feature of social organization or ecology independently promoted the ability for abstract information processing, or for mental modeling of interactions between external objects, then the spread of general intelligence could make tool use possible, just as it fosters all sorts of other competences. Only those species that, for other reasons, developed advanced forms of cognition would be able to reap the benefits of tool use. As with many speculations about the evolution of behavioral traits, these hypothetical versions of history are heuristic simplifications of what surely must have been a dynamic multifactor set of interactions. But they are valuable nonetheless, and can be examined at least indirectly in the light of this new evidence.

The hand-reared rooks studied by Bird and Emery (1) can shape hooks out of wire, use two tools in a sequence to achieve a goal, drop stones inside a tube to dislodge a platform holding a reward, select the properties of the stones they drop according to the needs of the task, and so on. Their behavior

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needs extremely limited prompting, and certainly no specific training for each task. This ability to operate tools in a species that does not normally do it is reminiscent of observations in primates, where capuchin monkeys, who are competent and keen tool users in captivity, are not thought to depend or even frequently use tools in the wild (7), although they do so in some populations (8). Bird and Emery are inclined to see tool-oriented behavior as an expression of what they call domain-general cognitive capacity, rather than as a dedicated tool-related competence with a causal role in the development of intelligence. This is certainly more parsimonious than the possibility that a common ancestor of rooks and New Caledonian crows developed its cognitive competence as a consequence of tool use, and present day non-tool-users retained the competence but lost the motivation, or happen to live in ecologies where these competences are not called into action. However, accepting—as the evidence points for the time being—that what distinguishes species that differ in tool use is not their ranking on a scale of cognitive sophistication simply shifts the weight to another foot: Might it be that tool use is the circumstantial outcome of growing up in a different ecological and social context rather than an adaptation characteristic of selected species? Or perhaps tool use is after all a selected trait (namely an adaptation) but not one in which selection promoted the information-processing capabilities associated with folk physics but rather one in which what was selected was the motivation to use objects as extensions of the animal's body. The view that tool use is not particularly demanding in cognitive terms (when compared to nest building) has been championed by Hansell and Ruxton (9), who argued that the number of species that use tools is small simply because using tools is rarely better than using morphological adaptations.

Evolution of Motivation or Evolution of Intelligence?

The possibility that tool use is a purely phenotypic trait can be safely excluded: both New Caledonian crows (10) and woodpecker finches (11) show tool-oriented behavior even if they are raised in the absence of tool-using models, whereas other corvids, including rooks, do not. In fact, juvenile New Caledonian crows manipulate objects in ways that anticipate future functional movements before they are skilled enough to reap any objective rewards from this behavior. Something in the ecology of this species must have favored individuals with an inclination to mediate their efforts to extract food by the use of external objects, most likely the presence of a significant resource that could not be exploited by using just beaks or claws. Whereas rooks are social foragers that seek earthworms and similar grubs in meadows and grasslands (12), New Caledonian crows frequently extract large wood-boring beetle larvae from decaying tree trunks (13). They inhabit an island with no specialized competitors (such as woodpeckers or aye ayes) and no native terrestrial mammals, a frequent source of carrion that many corvids exploit elsewhere. With hindsight, it is not difficult to postulate that selection may well have fostered the

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motivation to use tools rather than the capacity for physical cognition.

The parallel with issues surrounding the evolution of high intelligence in primates is notable. Tomasello and his colleagues (14) have postulated that "the crucial difference between human cognition and that of other species is the ability to participate with others in collaborative activities with shared goals and intentions: shared intentionality." In other words, motivation rather than more advanced information-processing. They postulate that humans have a unique motivation to share psychological states with others and unique forms of cognitive representation for doing so. High domain-general intelligence might not be what allowed for human sophistication in social cognition, but a consequence of it. Social motivation is instead postulated as causal in promoting selection for abstract cognitive representations. The notion that natural selection may act in many cases through the selection of motivation rather than of advanced cognition seems to be spreading, and the present report speaks in its favor.

Evolution Can Explain How Minds Work

The report by Bird and Emery (1) is valuable as a substantial empirical contribution to the distinctive features of tool-using species, but it is also significant in the wider frame of judging the appropriateness of considering shared ancestry as a factor in understanding the evolution of cognition. In a recent opinion essay, Bolhuis and Wynne (6) question what they call straightforward applications of Darwinism to cognition. They point out that different species may have arrived at similar solutions to cognitive problems because of shared selection pressures rather than because of being closely related. Surely to some extent their claim must be trivially true: what applies to the convergent development of white fur by arctic-bound, distantly related foxes and polar bears must surely apply to cognition: the laws of object relations are a property of the world, and animals will, even in the absence of recent common ancestry, acquire parallel concepts of folk physics if they are to be successful in acting upon the world that surrounds them. However, the recent developments in analyses of motivational or cognitive differences between human and nonhuman apes, and between corvids that do or do not use tools, prove that focusing on the comparison of traits between close relatives that differ in their behavioral phenotype is precisely what we need to understand the evolution of cognition. Contrary to the claims of Bolhuis and Wynne (6), the straightforward application of Darwinism to cognition seems a better idea day by day. Evolutionary convergence and divergence are two sides of the same biological picture, and any call for moving apart from one or the other is surely ill advised. In the case of tool use, the straightforward application of Darwinism implies enriching our knowledge of cognitive differences between close relatives, and relating this to the known ecology of the species in question.

Can "Insight" Be an Explanation?

There is yet another angle that deserves attention. Bird and Emery (1) refer to insight using Thorpe's (15) definition of a "sudden production of new adaptive responses not arrived at by trial behavior . . . or the solution to a problem by the sudden adaptive reorganization of experience" and claim that the behavior of the rooks must qualify as insightful. In other words, insight is inferred from the fact that the rooks could not have reached their solutions by trial and error, and is then invoked as causal, but its nature remains mysterious. This issue is ever-present in behavioral studies, as illustrated by the study of Epstein et al. (16), who showed that pigeons trained independently and conventionally in several tasks could, when necessary, chain them together according to the needs of a novel situation, thus fulfilling the letter (but not the spirit) of Thorpe's definition. Perhaps an analogue may be that of those lecturers who, after posing a complex problem to their audience, interject "and after some algebra, we get . . . ," whereby they produce an answer to the problem in the form of a simple and elegant formula whose origin continues to baffle the listeners. The behavioral biology equivalent is when, after describing an unexpectedly sophisticated set of actions, it is claimed that they could have been possible only by "insight" on the part of the animal.

The difference, however, is that whereas the lecturer may simply be economical with the details as a didactic temporary ploy that facilitates communication, the use of insight in animal behavior in an explanatory, causal role is as baffling as the problem that is supposed to solve. "Insightful" is a label often used for behaviors for which we do not have an information-processing hypothesis. Even in humans, the causal use of the term insight is ridden with difficulties, and it can hardly be claimed to explain much. Humans often attribute their own behavior to what they perceive as insights, but in many cases they can be shown to be wrong, whereas in others the label simply reflects ignorance of the origin of inspiration. The rooks' behavior is truly and unreservedly remarkable, but insight is, perhaps, best left alone.

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