动物学报 52(Supplement): 622–625, 2006
Acta Zoologica Sinica

S35-5 Tool manufacture by New Caledonian crows: chipping away at human uniqueness

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Abstract New Caledonian crows have evolved relatively sophisticated tool manufacture. We identify ten complex aspects that occur in their toolmaking, which is more similar to human toolmaking than that of any other nonhuman species, including chimpanzees. Crows provide living animal subjects for investigating those behavioral, cognitive and neural adaptations that allow species to move beyond chimpanzee-like tool manufacture.

Key words New Caledonian crow, Tool manufacture, Cognition

1 Introduction

A wide range of animals, from insects to humans, use tools (Beck, 1980), but we still know very little about how complex tool manufacture evolves. This is because toolmaking in nonhuman species has so far been found to be very simple. Skills considered necessary to move beyond chimpanzee-like toolmaking include a good understanding of, first, the physical relationships and functional properties of objects, and secondly, the intentions and goals of others (Heyes, 1993; Tomasello and Call, 1997; Povinelli, 2000). Research in the last 10 years has shown that New Caledonian crows (*Corvus moneduloides*) are complex toolmakers. We briefly summarize the complexities of their toolmaking, then compare them with those found in tool manufacture in other animals. An expanded version of this paper will appear in Hunt (2003).

Fig. 1 New Caledonian crows use and manufacture tools

2 Aspects of complex tool-manufacture in crows

2.1 Types of tools

New Caledonian crows make two distinct types of tools: stick tools and pandanus-leaf tools (Hunt, 1996). Stick-type tools consist of lengths of a range of stiff raw materials. The materials identified so far are twigs, bamboo stems, fern stolons, compound leaf stems, a slither removed from the stem of a palm leaflet and leaf petioles (Hunt, 1996, 2000a; Hunt and Gray, 2002).

Pandanus-leaf tools, on the other hand, are very flexible lengths of material that the crows cut and rip from the leaves of *Pandanus* spp. trees (Hunt, 1996). The manufacture of pandanus tools preserves a unique record for the study of toolmaking, because of the associated artifact of matching tool “counterparts” on leaves. These counterparts provide a complete artifactual history of the number and finished shapes of pandanus tools made at a site over the four years or so that leaves stay on trees (Hunt, 2000b).

2.2 Species-wide manufacture

New Caledonian crows use stick-type tools and pandanus tools throughout their range (Hunt and Gray, 2002, 2003). To April 2002, Hunt had collected 34 stick-type tools directly from birds on Grande Terre (10 sites) and Maré (2 sites), excluding tools collected in direct association with experimental work. Although a systematic survey of stick-type tools has not been carried out, our observations and information from local people indicate that the use of stick-type tools is widespread. Most of the stick-type tools were of material that had been modified to some degree (Hunt, 1996, 2000a; Hunt and Gray, 2002). Simple modifications include the breaking-off of dead twigs or the picking-up of fallen leaves and removing their petioles. When selecting live twigs, crows usually remove any associated leaves and sometimes shorten material before using the finished tool. More involved manufacture is required to make hooked tools (see hook tools). Birds may also simply pick up petioles and dead twigs from the ground to use as tools without modification.

Our survey of counterparts in 2000 showed that pandanus-leaf toolmaking is common as well as widespread (Hunt et al., 2001; Hunt and Gray, 2003). We sampled 21 sites and recorded 5 550 counterparts, generally collecting well over 100 counterparts at each site. These counterparts were only a small percentage of those on pandanus trees throughout New Caledonia; tens of thousands are probably present at any one time. All pandanus tools are manufactured.

2.3 Diversification

The making of stick-type and pandanus-leaf tools must have developed independently of one another once crows began to use tools. Within each of these tool-types, crows make tools to distinctly different designs (Hunt, 1996; Hunt and Gray, 2002, 2003). Crows have developed two distinct groups of stick-type tools: hooked tools (see hook tools) and non-hooked tools. Use of both types is widespread. Hooked-twig tools and non-hooked tools probably have a common historical origin, given the similarities in base material: all are stiff and stick-like in nature. The lack of hooked toolmaking in species like chimpanzees (*Pan troglodytes*) and woodpecker finches (*Cactospiza pallida*) also suggests that the initial form of a stick-type tool, in an evolutionary sense, is likely to have been non-hooked (Beck, 1980). Hooked-twig tools most probably represent a population-level diversification of stick-type tools.

The range of diversification in pandanus-leaf tools is greater. Our 2000 survey of tool counterparts showed that crows manufacture them to three distinct designs: wide tools, narrow tools and stepped tools (Hunt and Gray, 2003). Similarities in material and manufacture techniques, and the continuous geographical distribution of each design type which overlaps in the southeast of the Grande Terre (main island), together suggest that all three designs are closely related and have a common historical origin. It is very likely that there has been population-level diversification in the making of pandanus tools. The finished designs of both hooked-twig tools and pandanus tools are probably transmitted, not invented individually.

2.4 Hook tools

We have found three types of hooked stick-type tools: one made from twigs, another from the thorny stems of the compound leaves of a leguminous vine (*Caesalpinia schlechteri*), and one from the stolons of a *Nephrolepis* fern (Hunt, 1996; Hunt and Gray, 2002). A material-specific technique is required to make each of these hook-types. Hooked-twig tool manufacture is by far the most complex because it involves the creation of a hook where there had been none (see sculpted tools). Examination of hooked stick-type tools collected directly from crows, and observations of birds using them, indicates that the main working ends are the hooked ends.

The leaf-edge barbs on stepped pandanus tools only very rarely face the narrow working end of the tool. Therefore, stepped tools are hooked tools in which the hooks are natural. We know little about how crows use wide and narrow pandanus tools.

2.5 Targeting raw materials

Crows select material (pandanus leaf, fern stolon, thorny vine) that has naturally-occurring hooks (see hook tools). The birds do not need to use these materials to make non-hooked tools because suitable material for such tools is much more abundant in local rainforest. Crows also select specific tree species for material for hooked-twig tools. Eight of the nine hooked-twig tools that we collected at Pic Ningua between 1993 and 1995 were made from *Elaeocarpus dognyensis* (Hunt, 1996), whereas a family of crows that we observed in Parc Rivière Bleue in 2002 preferred to make theirs from *Cunonia vieillardii* (Hunt and Gray, 2003.). At both these sites the preferred tree species did not appear to be overly common in the rainforest. The advantages, if any, of using *E. dognyensis* and *C. vieillardii* are not known, but these trees have an abundance of forked twigs that are suitable for making hooked-twig tools. Crows also use the common, tougher-leafed pandanus species for toolmaking more often than material from less common, more fragile-leafed species (Hunt, pers. obs.).

2.6 Different tools for different foraging tasks

Crows appear to have developed different tools and associated manufacturing techniques to meet site-specific foraging needs. At Sarraméa in grazed woodland, crows commonly extract large cerambycid larvae with non-hooked tools (Hunt, 2000a). Tools there consist of a range of materials from leaf petioles to twigs that seem to be obtained mostly at the site of use. The crows commonly use them to “fish” for larvae in artificial holes drilled in dead logs, often extracting larvae clasped by their mandibles on to the ends of the tools.

High densities of large cerambycid larvae are restricted to areas outside primary rainforest where the softwood *Agathis moluccana* grows. In primary rainforest, invertebrate prey appear to be generally much smaller and without large mandibles. Here crows search in the multitude of places where prey cache themselves, as in the ends of broken branches and bases of pandanus and palm leaves (Hunt, pers. obs.). Hooked tools seem to offer advantages in this habitat, and this is where we have collected most of them. We do not know whether individual birds use different tools for different foraging tasks.

2.7 Sculpted tools

Sculpting tools involves modifying raw material to arbitrary shapes. The shapes are arbitrary because they are formed largely by the toolmaker and little constrained by the raw material. Crows sculpt regular, two-dimensional tool shapes from the edges of pandanus leaves (Hunt, 1996, 2000b). There are obvious constraints on the finished shapes because of the two-dimensional nature of pandanus leaf, the narrowness of leaf edges and the strong parallel fibers. Nevertheless, that crows make wide, narrow and stepped tools from the same raw material demonstrates that each of these distinct designs is arbitrary.

The hook tools that crows make out of live twigs often have pointed hooks on their wide ends (Hunt, 1996; Hunt and Gray, 2002). These hooks cannot be created by simply pulling twigs off adjoining stems. Instead, the hooks on hooked-twig tools are sculpted out of the forks at the stumps with adjoining stems, which the birds then sharpen and refine with the bill (Hunt and Gray, in prep.).

2.8 Rule systems

At any one site, pandanus-tool designs are usually quite similar in shape (Hunt, 2000b; Hunt and Gray, 2003). Crows therefore manufacture them to regular, arbitrary designs from some kind of instruction stored in memory (Hunt, 2000b). We do not have the same comprehensive data for hooked-twig tools as we do for pandanus toolmaking. However, an adult and its dependent offspring observed over two weeks both followed the same basic steps when making them (Hunt and Gray, in prep.). So we suspect that hooked-twig tools are also manufactured to some kind of rule system stored in memory. Experiments are required to determine the nature of the rule systems that crows use and whether this behavior is goal-directed.

2.9 Lateralization

The manufacture of stepped pandanus tools is lateralized, not only at population level (Hunt, 2000b) but also at species level (Hunt et al., 2001). We looked at the position of stepped-tool counterparts on leaves at 19 sites throughout Grande Terre and found that birds preferred to make these tools on the left edges of leaves rather than the right. We speculated that left-edge bias might be caused by the specialization of the right-eye/left-hemisphere system for complex sequential tasks in birds (Rogers, 2002); but the contralateral visual system responsible for the bias needs to be established experimentally. We have not investigated laterality in the toolmaking of individual crows or in the way they use the tools.

2.10 Cumulative change

Cumulative change in tool manufacture is indicated when three criteria in the design of different tools are met: (i) the designs belong to the same lineage, (ii) they have non-recapitulating manufacture techniques, and (iii) they vary in complexity and/or adaptive characteristics as improvements are incorporated over time. Such criteria are met in the stone tools produced by early humans (Tomasello et al., 1993; Foley and Lahr, 1997). The pandanus tools of the New Caledonian crow also appear to meet thm (Hunt and Gray, 2003). We have already presented evidence for a common lineage in wide-, narrow- and stepped-pandanus-tool designs (see Diversification). There is also no recapitulation in the making of the three designs, that is, at no stage in the process is one design modified from another. Furthermore, stepped tools are more complex than either wide or narrow tools: (i) they are both sturdy and narrow-ended at the working end, in contrast to wide and narrow tools which are either sturdy or narrow-ended, but not both, and (ii) the technique of their manufacture is more complex than that for wide or narrow tools. Stepped tools have probably developed through the following series of evolutionary changes: non-tapered tools led to one-step tools, which in turn led to multi-step tools. The functional differences associated with these different tool shapes still need to be determined.

3 Comparison with other tool users

A comparison of toolmaking in animals shows that crows have a wider range of complexities in their tool manufacture than reported for any other species except humans (Table 1).

Table 1 Specialized features of tool manufacture at taxon level in free-living vertebrates

	Brown-headed nuthatch	Woodpecker finch	Crow	Orangutan	Chimpanzee	Humans
Distinct types of tools	---	---	+	---	---	+
Species-wide manufacture	?	?	+	?	+	+
Diversification	---	---	+	---	---	+
Hook tools	---	---	+	---	---	+
Target tool material	---	?	+	---	?	+
Different tools for different tasks	---	?	+	?	+	+
Making tools to rule systems	---	---	+	---	---	+
Lateralization	---	---	+	---	---	+
Sculpted tools	---	---	+	---	---	+
Cumulative evolution in tool design	---	---	+	---	---	+
Social transmission	---	---	?	+	+	+
Cultural variation	---	---	?	+	+	+

Reference sources in Hunt (2003). + = attribute present; ? = attribute might be present.

4 What mechanisms underlie toolmaking in crows?

Many of the specialized features in crow toolmaking have parallels elsewhere only in the cultural behaviors of humans. Is crow toolmaking therefore based on social transmission of information and complex tool-related cognitive capabilities? The nature of crow tool manufacture, involving a diversity of tool types, raises the possibility that its complexity may be the consequence of a well-developed understanding of the physical world. This is supported by recent experimental work suggesting that crows may have considerable tool-related cognitive abilities (Chappell and Kacelnik, 2002; Weir et al., 2002; Pain, 2002). There is also circumstantial evidence that transmission of tool know-how in crows involves social learning. First, it is unlikely that the different tool designs that crows use are “extended phenotypes” reflecting underlying genetic differences. Significant genetic differences even between crows at distantly separated sites on Grande Terre seems a remote possibility because the island is relatively small (ca. 400 km long and 50 km wide), and crows, although not great flyers, are still highly mobile and young are dispersive. Woodpecker finches, which can develop tool use even without social contact, still rely heavily on individual learning (Tebbich et al., 2001).

Secondly, crow pandanus-tool manufacture appears to meet criteria used to identify traditional behavior (Whiten et al., 1999; Avital and Jablonka, 2000). It is habitual, the shapes of pandanus tools are generally quite similar at individual sites compared to differences between sites, the complement of pandanus-tool designs differs between sites in ways that suggest they have a common historical origin, and the shape variation in a pandanus-tool design, and consistency of shape at a site, lacks an obvious ecological explanation (Hunt, 2000b; Hunt and Gray, 2003).

Moreover, the case for both individual and social learning in the development of crow tool manufacture is plausible considering shared characteristics between *Corvus* species and primates. These include highly encephalized areas of the brain that seem to deal with so-called “intelligent” behavior (Rehkämper and Zilles, 1991), behavioral flexibility and considerable cognitive capabilities (Heinrich, 1995; Zorina, 1997; Fritz and Kotrschal, 1999), and social behavior that can provide substantial parental care for offspring (Heinrich, 1999).

5 Conclusion

There is still much to be learnt about the evolution, development and natural history of tool manufacture in New Caledonian crows. Nevertheless, our research over the last 10 years has shown that they have evolved sophisticated toolmaking skills. This is scientifically interesting not only because of what it says about crow cognition and capabilities, but also because of the insights that might be gained about the evolution of complex tool manufacture and cognition. Crow tool manufacture has already demonstrated that capacity for making hook tools and regular, arbitrarily-shaped instruments does not require large brains, manipulatory limbs or symbolic attributes.

Acknowledgements We thank Gisela Kaplan for inviting us to present our research to this symposium. The work was funded by an Auckland University Research Council grant to R.D. Gray, G.R Hunt and Michael Corballis.

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