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ORIGINAL ARTICLE

Gavin R. Hunt · Russell D. Gray

Direct observations of pandanus-tool manufacture and use by a New Caledonian crow (*Corvus moneduloides*)

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Abstract New Caledonian crows are reported to have impressive pandanus-tool manufacture abilities. These claims are based on an extensive artefact record. However, inferring behavioural and cognitive abilities without direct observation of tool manufacture is problematic. Here we report (and document on video) direct observations of a crow making and using stepped pandanus tools at Pic Ningua. We observed (1) a bias for making tools on left edges consistent with that previously found at the site, (2) faithful manufacture of a stepped design with high overall congruence in the shapes of tools, (3) the use of convergent rips to first form the tapered end working away from the trunk then the wide end working towards the trunk, (4) appropriate functional use of stepped tools by use of the leaf-edge barbs to hook food from holes, and (5) consistent holding of tools on the left side of its head when using them. Our observations verify most of the claims based on the artefact record, but the crow's exact manufacture technique was slightly different to that inferred previously.
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Keywords New Caledonian crow · Pandanus-tool manufacture and use · Laterality

Introduction

The manufacture of distinctively shaped tools is thought to require sophisticated cognitive skills (Donald 1991; Wynn 2002). New Caledonian crows (*Corvus moneduloides*) shape tools out of the barbed edges of *Pandanus* spp. leaves (Hunt 1996, 2000a; Hunt and Gray 2003a). They manufacture three distinct tool designs: one wide, one narrow, and one tapered by a sequence of cuts and rips (Hunt 2000a; Hunt and Gray 2003a). What we have documented about crows' pandanus-tool manufacture and use is mostly inferred from artefactual evidence and tools collected off crows. Features of this tool manufacture and use include: (1) the use of barbs as hooks to aid prey capture (Hunt 1996), (2) the imposition of two-dimensional shape on material (Hunt 1996, 2000a), (3) the making of each design in a unique 'one-step' process with no evidence that tools are subsequently modified after their removal from the leaf edge, (4) an ability to align converging rips with a high degree of accuracy (Hunt 2000a; Hunt and Gray 2003a), (5) the diversification and likely cumulative evolution of pandanus tools, (6) a high overall congruence in the shapes of tools of each design at sites (Hunt 2000a; Hunt and Gray 2003a), and (7) species-level laterality in the manufacture of stepped tools because most crows prefer to remove them from the left edges of leaves rather than the right edges (Hunt et al. 2001).

Crows' pandanus tool manufacture and use contrasts dramatically with what is known about tool manufacture and use by other nonhumans. The seven features above are unknown for habitual behaviour outside crows and humans. Most reports of tool use in nonhumans only involve a very small number of individuals for whom the behaviour is not known to be habitual (Beck 1980; Lefebvre et al. 2002). For example, an American crow (*Corvus brachyrhynchos*) was reported to have used a piece of bark as a tool (Caffrey 2000). Species where individuals habitually manufacture tools in the wild at the population level are extremely rare (Beck 1980; Lefebvre et al. 2002). They are New Caledonian crows, orangutans (*Pongo pygmaeus abelii*) (van Schaik et al. 2003) and chimpanzees (*Pan troglodytes*) (Whiten et al. 1999). Woodpecker finches (*Cactospiza pallida*) (Eibel-Eibesfeldt 1961; Tebbich et al. 2002) and African (*Loxodonta africana*) and Asian (*Elephus maximus*) elephants (Chevalier-Skolnikoff and Liska 1993; Hart et al. 2001) commonly use tools, but data on their manufacture of tools in the wild is lacking. Individuals of species other than crows only modify material in simple ways and do not produce distinctive tool shapes. Tool manufacture gener-

G. R. Hunt (✉) · R. D. Gray
Department of Psychology, University of Auckland,
92019 Auckland, New Zealand
Tel.: +64-9-3737599, Fax: +64-9-3737450,
e-mail: grhunt10@hotmail.com

ally involves only breaking off material and some trimming. Chimpanzees, whose tool behaviour is diverse, mostly modify branches into probes for extracting food (McGrew 1992). They generally remove side extensions and leaves, and occasionally shorten sticks. The simple level of their tool manufacture may be related to a poor grasp of 'folk physics' (Tomasello and Call 1997; Povinelli 2000). For example, chimpanzees demonstrate little understanding of how to make and use hooks (Sugiyama and Koman 1979; Povinelli 2000). Orangutans also make probing tools by modifying branches in a chimpanzee-like way. An orangutan and several chimpanzees have been observed making and using tools to obtain out-of-reach branches (Sugiyama and Koman 1979; Fox and bin'Muhammad 2002). This behaviour has been described as 'hooking' (Boesch 1996; Fox and bin'Muhammad 2002), but its description as 'branch-hauling' is more accurate because the tools are usually not hook-shaped and for those that are, there is no evidence of any intention to manufacture hooked instruments (Sugiyama and Koman 1979; McGrew 1992; see Discussion in Hunt 2000a and Hunt and Gray 2002).

The manufacture of a pandanus tool creates a matching outline, or 'counterpart', of its shape on the leaf edge. The shape of a tool is easily obtained from its counterpart. This system provides a comprehensive artefact record of current pandanus tool manufacture in the last several years. Uncompleted attempts at manufacture are also valuable for inferring the sequence of actions used to make tools. From such evidence Hunt (1996, 2000a) inferred that birds generally form the tapered end of stepped tools first, working towards the leaf tip. Then they form the wide end working towards the trunk. To efficiently remove a pandanus tool using convergent rips, the rips need to be well aligned. Almost completed tools with badly aligned rips are sometimes found still attached to leaves (G.R.H. personal observation), demonstrating that misalignment of rips can create manufacture problems. However, misalignment is rare, suggesting that crows have the ability to align convergent rips. Hunt also inferred that a crow's head was right-way-up when making pandanus tools and that the right side of its head was mainly involved in the removal of stepped tools from left edges. This led Hunt et al. (2001) to suggest that the species-level laterality in stepped tool manufacture might reflect the specialization in vertebrates of the left-hemisphere/right-eye visual system for sequential tasks (Rogers 2002). Crows had been observed carrying and using pandanus tools but never making them (Hunt 1996). Therefore, the findings above are mostly based on artefactual data and circumstantial evidence of individual crow behaviour. Inferring behaviour and cognition from artefacts alone is fraught with difficulties (e.g. Liberman 1991; Jeffares 2002). For example, the uncompleted attempts made by crows which were used to infer the sequence of manufacture could have resulted from incorrect manufacture techniques. Direct observations of individual crows making and using pandanus tools are thus needed to check the artefactual-based inferences.

To provide this missing evidence we set out to observe crows manufacturing and using pandanus tools at Pic Ningua, New Caledonia. Crows there manufacture the stepped design almost exclusively. We know this from counterparts collected in 1993 (Hunt 1996), 1997 (Hunt 2000a) and 2000 (Hunt and Gray 2003a). Birds on the peak also make stepped tools significantly more on the left edges than the right edges, but the ratio of left-edge use to right-edge use is greater on trees with clockwise-spiralling leaves compared to those with anticlockwise-spiralling leaves (Hunt 2000a). This spiralling-direction effect is consistent with birds having a bias for left edges, combined with the greater accessibility of these edges on clockwise-spiralling leaves (trailing edges) than anticlockwise-spiralling ones (leading edges).

In this study we report a simple initial experiment designed to investigate stepped tool manufacture, including (1) manufacture technique, (2) any lateralized behaviour in the making of tools, (3) whether or not the leaf-edge barbs are used as hooks, and (4) variation in the two-dimensional shapes of tools. Our findings verify most, but not all, of the artefactually-based claims previously reported.

Methods

Study site

Pic Ningua is a 1,343 m high, relatively insular peak situated within the central mountain chain of Grande Terre, New Caledonia (21°45′S, 166°8′E). On 5 July 2001, we set up a feeding site in cloud forest at 1,100 m above sea level on the northeastern slopes of Pic Ningua. We constructed two temporary feeding tables 4 m apart out of forest materials. On each table we placed food of various kinds on trays and small pieces of meat in holes (7–8 cm deep and 2.6 cm in diameter) that we drilled in a dead log. All meat was beef, but the pieces varied in size and texture. Our hide was 6 m from the closest table and 10 m from the furthest one.

Subject and experimental design

We positioned a young pandanus tree with clockwise-spiralling leaves on the furthest table from the hide (tree A) (see closeup of tree in Fig. 4a). By 12 July, a crow was regularly extracting meat out of the holes in the log, using its bill and occasionally stick tools. On 12 July it made a multi-step pandanus tool from tree A and used it to extract meat in the log. Between 12 and 16 July, it returned repeatedly to the feeding site and made pandanus tools to extract meat. We filmed many of these tool manufactures and collected most of the tools. When possible, we also collected pandanus tools that the crow brought to the site.

By the evening of 16 July we had sufficient examples of tool manufacture on tree A (>20) and removed it. From 17 to 23 July, a tree with anti-clockwise-spiralling leaves was positioned on the table closest to the hide (tree B). The crow was now habituated to the hide and camera set up, so we used the closest table to film the crow's behaviour in greater detail. Trees A and B were young trees with little trunk. Their leaves were of similar lengths (2–3 m long), but those on tree B were more fragile than those on tree A. There were no counterparts on trees A and B when we positioned them on the tables. By the evening of 23 July we had sufficient examples of tool manufacture on tree B (>20) and ended the experiment by removing the tree. We removed all counterparts off trees A and B when data collection ended, but uncompleted tool manufacture attempts were removed during the experiment to prevent their possible completion at a later time. Counterparts and tools were stored in 70% ethanol to minimize shape distortion. We observed all but five of the tool manufactures on trees A and B.

Although we could not conclusively identify individual crows from physical characteristics, several reasons convinced us that only one individual was manufacturing pandanus tools on trees A and B. First, we only saw one bird at a time make a pandanus tool. Second, for most of the experiment only one bird descended to the tables to feed. Third, between 13 and 23 July the visits to the site by a crow to feed were regularly spaced (mean±SE, 114.6±10.1 min, n=27). Last, we did not observe any variation in behaviour that might have suggested more than one individual was manufacturing the tools.

From the video footage, we documented the time it took to (1) manufacture a tool, and (2) extract each piece of meat. A manufacture trial began when the crow first touched the leaf with its bill, and ended as soon as the tool was separated from the leaf. An extraction trial began when the tool was inserted into the hole, and finished as soon as the meat was removed. It was terminated if the bird moved to another hole or stopped probing for 10 s or more.

Table 1 The shapes of stepped tools made (n=40) or brought (n=5) to the feeding site by the crow. Description of the taper measurement is in Fig. 3

		Mean±SE (cm)
Made on trees A and B	Length	18.1±0.53
	Width	0.9±0.02
	Taper	8.1±0.34
	Steps	2.0±0.08
	Taper/length	0.5±0.02
Brought to the site	Length	15.6±0.84
	Width	0.8±0.05
	Taper	6.4±0.65
	Steps	2.2±0.37
	Taper/length	0.4±0.05

Results

Shape characteristics of tools and location of manufacture

From 12 to 16 July, the crow manufactured 21 stepped pandanus tools on tree A, 17 of which we collected (Fig. 1). Two of the 21 tools had one step, 14 had two steps and four had three steps. The remaining counterpart was inadvertently damaged by us, but it was clearly a stepped tool. In addition, it made three uncompleted manufacture attempts. From 17 to 23 July, the bird manufactured 21 stepped pandanus tools on tree B, 13 of which we collected (Fig. 1). Five of the 21 tools had one step and 16 had two steps. There were four uncompleted manufacture attempts. The crow also brought six stepped tools to the site and used them to extract meat, five of which we collected. Two of these had three steps, two had two steps and one had only one step. Tool measures for the tools made on trees A and B did not differ significantly from those it brought to the site (Table 1).

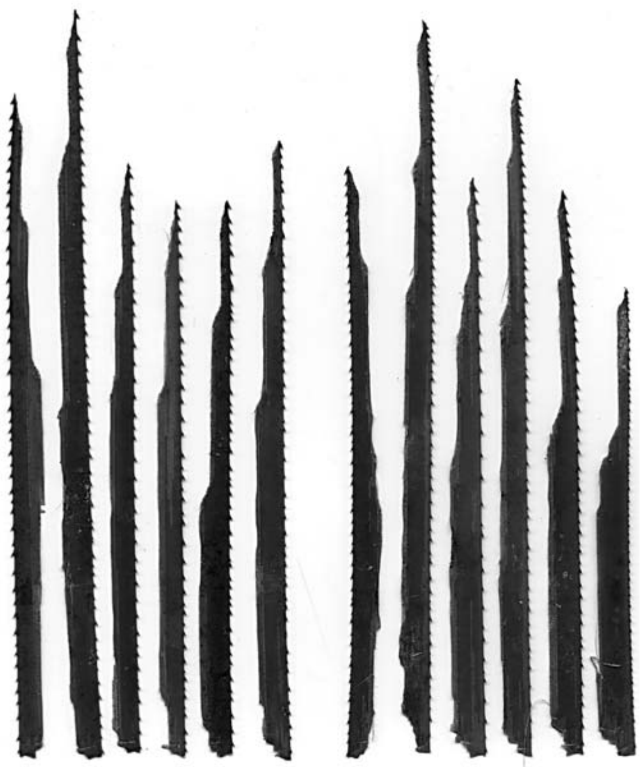
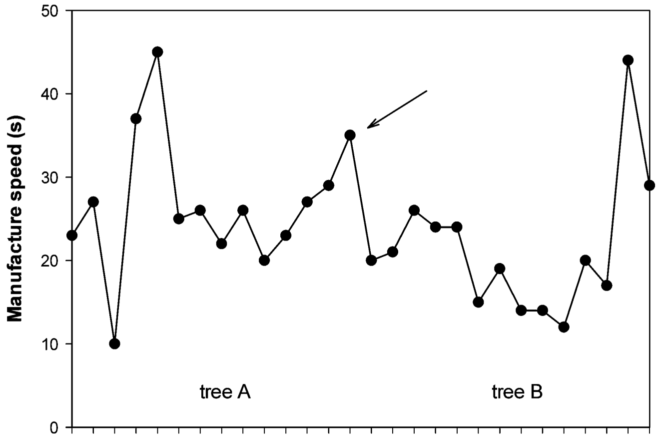


Fig. 1 A selection of pandanus tools made by the crow on tree A (*first six from the right*) and tree B. Tools with barbs on their right edge were made on left edges. The tool *third from left* (17.7 cm long) is that being manufactured in Fig. 4b and in Electronic Supplementary Material, S1

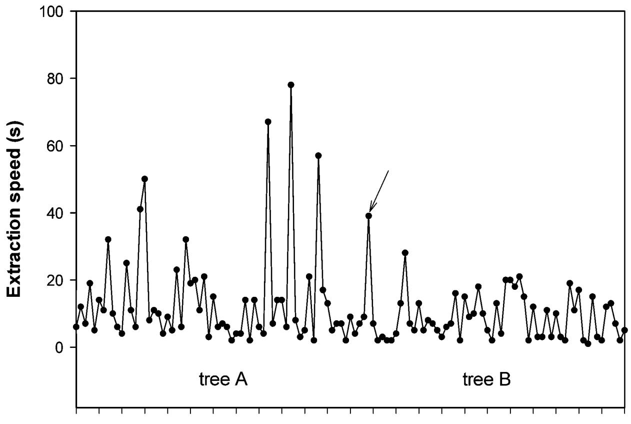
On tree A, the crow made 17 tools on left edges (81%) and four on right edges (19%). All three uncompleted manufacture attempts were on left edges. When each of the four tools was manufactured on a right edge, a counterpart was already present on the left edge. On tree B, 14 tools were made on left edges (67%) and seven on right edges (33%). Three of the four uncompleted manufacture attempts were on left edges, and one was on a right edge. The latter attempt was made on a leaf with a counterpart on the left edge. When a tool was made on a right edge, in only three of the seven cases was there a counterpart present on the left edge. Three of the six tools it brought to the site were made on right edges, two were made on left edges, and the edge on which the fourth tool was made is unknown. A sample size of one for each spiral direction meant that we could not separate out possible effects on tool shape related to physical differences between the trees.

Description of manufacture

There was no change in the crow's manufacture speed over time (Fig. 2a). As inferred previously, stepped tool manufacture involves a series of distinct cuts across the leaf fibres and longitudinal rips parallel to the fibres (Fig. 3). The crow always first shaped the tapered end, working away from the trunk. This meant that the barbs on tools always faced away from their narrow ends because barbs along the leaf edges point towards leaf tips. It then formed the wide end and removed the tool, working towards the trunk (Fig. 3; see Electronic Supplementary Material, S1). When



(a)



(b)

Fig. 2 **a** Variation in the speed to manufacture stepped tools. The 28 trials are sequential over the period of the study. There was no change in manufacture speed over the study (Regression: $F_{1,26}$= 0.48, P=0.50). **b** Variation in the speed to extract a piece of meat with a stepped tool. The 121 trials are sequential over the period of the study. There was an increase in extraction speed over the study (Regression: $F_{1,119}$=7.07, P=0.009). The *arrow* on each graph indicates the last trial associated with tree A

it cut the last step on the tapered end, it always made a rip of varying length from the step towards the tip of the leaf (rip A in Fig. 3a). From the video footage and inspection of counterparts and tools, the crow appeared to mostly make cuts to form the wide end past the end of rip A. It then ripped the leaf edge back towards the trunk (rip B in Fig. 3a) to meet rip A. Misalignment of rips was usually difficult or impossible to detect visually. At no time did we see the crow attempt to modify a tool after it was removed from the leaf edge.

The orientation of the crow's head when making a tool was different to that inferred previously. To manufacture a stepped tool it made all cuts that we saw with its head inverted, that is, the upper mandible was placed under the edge and the lower mandible was on top of the edge (Fig. 4a, b; see Electronic Supplementary Material, S1). The crow did this mostly standing behind the leaf edge, either on the leaf from which the tool was removed (Fig. 4a, b) or on another leaf and/or the table (22 of the 28 manufactures observed). It also made four of the 28 tools when standing facing the leaf edge. In the remaining two cases, it removed tools with a combination of standing facing the leaf edge and standing behind the edge.

Use of stepped tools

We videotaped the crow extracting 121 pieces of meat from the holes in the log with 27 different stepped tools that it made at the site, and two that it brought to the site. It extracted the meat in 11.6±1.1 s (n=121), but did so faster in the second half of the experiment (tree B) compared to the first half (tree A) (Wilcoxon 2-sample test: Z=–2.12, n=121, P=0.034). As a consequence, there was a significant increase in extraction speed over the period of the study (Fig. 2b). However, inspection of Fig. 2b reveals that this result is probably due to relatively few long extraction times associated with tree A. The crow always released the tool from its bill before eating a piece of meat, either dropping it or placing it on the log. If it dropped a tool on the ground it attempted to retrieve it. The crow usually left its tool behind when leaving the feeding site, mostly because it carried meat away in its bill. On several

Fig. 3 **a** Diagrammatic representation of what appeared to be the main manufacture method used by the crow to remove a stepped pandanus tool (the tool is 2-stepped and 18 cm long). The trunk end of the leaf is *towards the right*. The method involves two distinct sets of cuts and rips. Work is first carried out away from the trunk to make the tapered end, culminating in rip A. Two cuts that form the wide end are then made past the end past of rip A and the tool **b** is finally removed with a well-aligned rip (rip B) back to meet rip A. The sequence of each combined cutting and ripping action is indicated by numbers 1–4 in *circles*

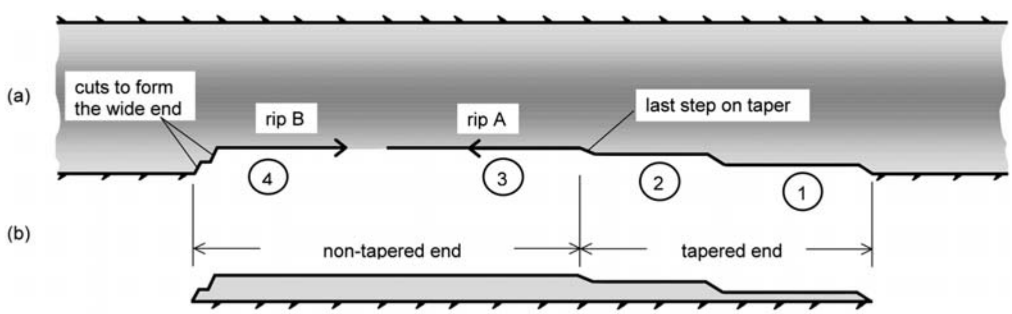


Fig. 4 **a** The crow making a cut to form the tapered end of a tool on the left edge of a leaf on tree A. The crow is working towards the leaf tip while standing behind the edge. **b** The crow forming the wide end of a tool on tree B, working towards the trunk (see the complete manufacture in Electronic Supplementary Material, S1, and the finished tool in Fig. 1). Note that a central reinforcing trough separates the left and right edges of a leaf

occasions it attempted to pick up its tool to take away but could not grasp it because its bill was full of food.

The crow always used the narrow end as the working end, which meant that the barbs on the leaf edge could function as hooks. When using a tool, the non-working end was mostly positioned laterally on the left side of the head, with the working tip angled over in the right visual field (88 of the 121 extractions). For 32 extractions it held the wide end of the tool in its bill, either with no detectable laterality or still with the tool tip over in the right visual field. On one occasion it held the tool on the left side then switched to holding it non-laterally. At no time did the crow hold any of the 29 pandanus tools that we observed on the right side of its head.

When using a tool to extract meat, the crow mostly held tools with the barbed edge facing away from its head (109 of the 121 extractions) rather than towards it (2 extractions with the tool held non-laterally by the wide end and 2 with the tool held laterally between the tip and wide end). In six cases, it first placed the tool in the hole or used it briefly with the barbed edge facing inwards before rotating the tool so that the edge faced outwards. For the remaining two extractions we could not tell which direction the barbed edge faced.

Stepped tools were not stiff enough to lever meat out of holes. However, the tapered shape did provide enough stiffness so the barbed edge could be forced, or brushed, up against the meat to attach it to the tool so it could be pulled out. We often observed tool use that suggested the crow was brushing the tool tip up against the meat in the hole so that the barbs would hook onto it. Although extraction times were faster in the second half of the experiment, the crow was proficient at hooking meat out from its very first attempt.

The crow discarded four tools after unsuccessfully using them and immediately made other tools that it used to extract meat. In each case the reason for discontinuing use appeared to be a poorly functioning tool. In one of the four cases the tip of the tool that it made was cut out where the leaf edge was decayed and the barbs were missing or damaged at the tip. In two cases, the crow lost a tool on the ground and returned to the table with non-stepped strips of pandanus leaf-edge that we had discarded there (we had removed these strips from another tree and used them to extract meat from the holes in the log). In the final case, it discarded a tool that we had made from a different pandanus tree and placed in a hole, having first removed the barbs at the tip of the tool. On one occasion we also saw the crow discard a tool that it had just made but not used, then immediately make another to use. The discarded tool was the shortest it made or brought to the site during the experiment (length=10.3 cm).

Discussion

Our observations of pandanus tool manufacture and use are generally consistent with the inferences we made from tools collected off crows and the record of tool counterparts. The crow manufactured these tools (1) on leaves that spiralled in both clockwise and anticlockwise directions, (2) with a strong bias for left edges, especially on clockwise-spiralling leaves, (3) working in convergent directions using a consistent sequence of actions, forming the tapered end first then the wide end, (4) with a high congruence in their two-dimensional shapes as shown by the small standard errors in Table 1, and (5) in a ‘one-step’ process and did not modify them after their removal from leaves.

The most obvious difference between the crow’s actual behaviour and that inferred from the artefact record was that the crow inverted its head to make a tool. Are there any obvious reasons that head inversion might be preferred over non-inversion? Head inversion offers a bird flexibility as to where it positions itself to make a tool: it can sit on or stand behind the leaf used to make a tool, as well as face it. Facing the leaf might be the only position in which a crow could make a tool with its head right-way-up. We have subsequently observed several crows on the island of Maré, New Caledonia, using the same inverted technique to make wide pandanus tools (Hunt and Gray, unpublished data). If head inversion is universal amongst crows, there might be a morphological or physiological reason for this behaviour. For example, when inverting the head the more powerful upper mandible probably bears most of the cutting force on the bill.

The inverted manufacture technique meant that the crow we observed used the left side of its bill to make cuts when forming the tapered end on left edges, and the right side when forming the wide end. The inverse applied when tools were removed from right edges. However, its right eye could still be primarily guiding manufacture, especially as work with the bill tip is probably done with binocular vision (Hunt 2000b; Rutledge and Hunt 2003). Eye patching experiments with captive birds manufacturing stepped tools can only determine which contralateral visual system, if any, is specialized for manufacture.

An aspect of manufacture that was difficult to see in detail, even with video footage, was the technique for forming the non-tapered end of a tool to finally remove it from the leaf. From examining artefactual material, Hunt (2000a) inferred that the common method to make a stepped tool involved cutting and ripping away from the trunk then towards it. He also inferred that the converging rips were closely aligned. The crow we observed appeared to mostly use this method to make a tool, and made converging rips that aligned with a high degree of accuracy (Fig. 3).The close alignment would seem to require visual assessment of the distance of rip A in from the leaf edge and then making cuts at the wide end to match it. Work in captivity suggests that crows may be able to access the distance to food and then select a tool of suitable length to extract it (Chappell and Kacelnik 2002).

The crow had a bias for left edges, but the bias was weaker on tree B with anticlockwise spiralling leaves (81% of tools made on tree A, and 67% on tree B). Previously at Pic Ningua, Hunt (2000a) recorded 89% of tools on the left edges of clockwise-spiralling leaves, and 71% on the left edges of anticlockwise-spiralling leaves. These results are strikingly similar and probably reflect poorer access to left edges on anticlockwise leaves (Hunt 2000a). They suggest that most crows at the site might have a bias of similar strength for left edges. We also found that the strength of the crow's bias was probably influenced by the availability of space on the leaf that it chose to make a tool; in all four cases when it used the right edge on tree A the left edge had already been used. Two of these four cases occurred early on in the experiment when unused leaves on the tree A were plentiful, therefore use of the right edge may have been more influenced by the availability of edges close to the bird as it stood in the tree. Multiple tool manufacture on the same leaf edge often occurs on trees with high numbers of counterparts (G.R.H. personal observation), but the crow we observed only made at most one tool on a leaf edge. The crow was not only lateralized for tool manufacture, but also in the way it used the tools. This is the first reported case of lateralization in both the manufacture and use of tools in nonhumans.

The manufacture and use of hooks appears to be cognitively difficult given that modern humans are the only primate we know of that has unequivocally mastered this task (Yellen et al. 1995). Crows craft crochet-hook-like tools out of twigs, generally using the hooked ends as the working ends (Hunt 1996; Hunt and Gray 2002, 2003b). A captive female New Caledonian crow, Betty, supplied with hooked tools made out of wire used them appropriately to extract a small bucket containing food (Weir et al.2002). To do this she had to insert the end of the wire under the bucket handle in order to hook or lever the bucket out. Betty later made her own tools by bending straight wire to various angles, including into hooks, and then used them to successfully carry out the same task.

Our observations of stepped tool use raise interesting questions about the extent to which crows grasp the functional properties of these tools. We found that the crow extracted food with these tools (1) always using their narrow ends and therefore with the barbs facing away from the working tip, (2) by holding them consistently against the left side of the head, (3) by mostly positioning their barbed edge away from the side of the head, (4) by efficient use of their barbs to hook it out, and (5) after replacing those clearly defective with effective ones.

The crow we observed was skilled at using the barbs as hooks to successfully extract meat, as shown by the short extraction times. It was probably experienced at using stepped tools to extract prey in the forest, but not at using them to extract small pieces of meat-like prey from vertical holes. It appeared to actively brush the barbed edge up against the meat, which necessitated correctly orientating the edge in relation to the meat. Crows commonly lever meat out of holes with stick tools (Hunt and Gray, unpublished data), but the crow we observed never appeared to attempt this with a stepped tool. Indeed, it discarded two tools that lacked barbs at the tip. Nevertheless, skilled manufacture and use of tools does not necessarily imply a good understanding of their functional properties. For example, that the leaf-edge barbs faced away from the narrow end may simply be a consequence of procedural knowledge or rote behaviour to always form the tapered end working away from the trunk.

While recognising the need for caution in assigning functional understanding, our present findings are at least consistent with the claim that, unlike chimpanzees, New Caledonian crows grasp some of the functional characteristics of their tools (Hunt 1996; Weir et al 2002). For example, it promptly discarded defective tools. The findings further suggest that crows make and use pandanus tools because of their hooking affordances (Hunt 1996; Hunt and Gray 2002, 2003b). The crow showed that their barbed, stiff and narrow-ended characteristics combined to make them highly effective implements for meat extraction. We have proposed that crows evolved stepped tools from the simpler versions that they make (Hunt 2000a; Hunt and Gray 2003a).

The shapes of the pandanus tools that the crow produced were highly consistent with the shapes of those documented at Pic Ningua from counterparts. That is, exclusive manufacture of stepped tools usually made to a two-step pattern. At other sites, crows can consistently manufacture distinctly different shaped stepped tools and pandanus designs (Hunt and Gray 2003a). This demonstrates that the shapes of pandanus tools are more determined by crow behaviour than constraints associated with the raw material (Hunt 2000a). Modern humans are the only other toolmakers whose tools are characterized by high shape fidelity (Tomasello et al. 1993). Human tool manufacture is based on the ability to hold a reliable mental image of a tool's design before it is made and pass on that design to others by social learning. Based on the different, overlapping geographic distributions of each pandanus tool design and their lack of ecological correlates, and the social learning abilities of *Corvus* species, we have suggested that pandanus tool manufacture is also likely to be transmitted via social learning (Hunt and Gray 2003a). We are currently investigating this possibility.

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