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Use of a barbed tool by an adult and a juvenile woodpecker finch (*Cactospiza pallida*)

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ABSTRACT

Here we describe the modification and use of a new tool type in the woodpecker finch (*Cactospiza pallida*). This species is known to habitually use twigs or cactus spines to extract arthropods out of tree holes. We observed an adult and a juvenile bird using several barbed twigs from introduced blackberry bushes (*Rubus niveus*) which the adult bird had first modified by removing leaves and side twigs. The barbs of blackberry tools provide a novel functional feature not present in tools made from native plants and de-leafing of twigs never has been observed before. Both birds were observed using several of these tools to extract prey from under the bark of the native scalesia tree (*Scalesia penduculta*). They oriented the twigs such that the barbs pointed towards themselves; this rendered the barbs functional as they could be used to drag prey out of a crevice. The juvenile bird first watched the adult using the tool and then used the tool that the adult bird had left under the bark at the same location and in the same way as the adult. Our observation highlights the fact that opportunities for the transmission of social information do occur in the wild and indicates that woodpecker finches are flexible in their choice of tool material and tool modification.

1. Introduction

During the last years there has been an intense debate about whether tool-using animals also can appreciate the functional properties of the tools that they use (reviewed in Emery and Clayton, 2009; Seed and Byrne, 2010). This question arises for example when animals modify tools for a specific purpose or when they selectively choose the appropriate tools when presented with an array of tools, some which are suitable to the task and some which are not. Because of the presumed cognitive complexity involved in tool modification and tool selection (Tomasello and Call, 1997) one might expect to find both abilities predominantly in tool-using apes. However, more and more examples of tool modification and selectivity come from tool-using birds, most notably from New Caledonian crows (*Corvus moneduloides*). This species regularly uses at least three different tool types and is known for its elaborate tool manufacture which includes cutting the barbed leaves of the *Pandanus* plant and using the barbs in a functional manner as well as sculpturing of hooks from the end of twigs in the wild (Hunt, 1996b; Hunt and Gray, 2002, 2004a,b). In laboratory experiments they selected tools of the appropriate length and diameter for a task at hand (Chappell and Kacelnik, 2002, 2004; Bluff et al., 2004). In the wild this species also uses the barbed vines of introduced *Lantana camara* which shows that they are not constrained to established plant-tool associations but can make flexible choices regarding tool material (Hunt, 2008). In this paper we describe a similar behaviour for a Darwin's finch, namely the modification of a barbed tool made from an introduced plant species by the woodpecker finch (*Cactospiza pallida*). Woodpecker finches already have shown remarkable flexibility of tool selection and modification in laboratory experiments (Tebbich and Bshary, 2004; Teschke et al., 2011; Teschke and Tebbich, 2011) but lab experiments alone may not be sufficient to infer the behaviour of wild animals (Emery and Clayton, 2004).

Woodpecker finches belong to the famous Darwin's finch clade and are known to use twigs from native bushes and trees, petioles of leaves and cactus spines from opuntia cacti (*Opuntia* sp.) to extract arthropods from tree holes and crevices (Eibl-Eibesfeldt, 1961). They also have been observed to modify twigs and cactus spines prior to use, shortening them if they seem too long and breaking off side twigs that would prevent insertion into tree holes. The ecological relevance of tool use in this species varies between vegetation zones. In arid habitats near the coast where seasonal variation in food availability is high and food is difficult to access,

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woodpecker finches spend up to 50% of their foraging time using tools whereas they rarely use tools at higher elevations – in the so-called Scalesia zone – where food abundance is stable year-round and food is easy to access (Tebbich et al., 2002).

We observed the manufacture of tools from twigs of introduced blackberry bushes (*Rubus niveus*) by an adult and a juvenile woodpecker finch in the Scalesia Zone of Santa Cruz Island, where tool use is infrequent. During the last 50 years, this habitat type has been strongly affected and reduced by human activity and the remnant Scalesia forest has been invaded by introduced trees and shrubs such as *Cedrela odorata*, *Cinchona pubescens*, and Blackberry (*Rubus niveus)* (Jäger et al., 2007; Rentíra and Buddenhagen, 2006). Especially the invasion with blackberry bushes has accelerated during the last 10 years (Mauchamp and Atkinson, 2011) and large areas of the understory are comprised predominantly of this species.

For woodpecker finches, barbed tools made of blackberry bushes provide an additional functional feature that is not present in the tools they make from native plants. This raises the question of whether woodpecker finches, like New Caledonian crows, use this new feature in a functional manner.

2. Methods

2.1. Study species

Woodpecker finches belong to the Darwin's finches which are endemic to the Galápagos Islands. Females and males are monomorphic but juveniles can be distinguished from adults by their brighter beak coloration. Woodpecker finches have an elongated beak that is suitable for probing moss patches and pecking into wood and under bark to gain access to their prey. They mainly feed on arthropods, but also on nectar and fruits.

2.2. Behavioural observations

On December 10, 2008, all four authors watched tool use with a barbed blackberry twig by an adult and a juvenile woodpecker finch on Santa Cruz Island of the Galapagos archipelago in the Scalesia Zone (0°37′28.10″S/90°23′9.50″W). E.C. took photos with a Canon EOS Digital Rebel XTi (10 megapixels) using a 75–300 mm zoom lens (tool A–G, Table 1) while S.T. commented the observation and recorded the comments on a mini tape recorder. The tape recording started shortly after the first picture was taken and therefore the first tool (tool A, Table 1) is not in included in the transcript of the tape recording of behavioural observation. The observation was made from a distance of approximately 7 m. On the morning of January 15, 2009, I.T. observed another instance of blackberry tool use in the same area, in 345 m distance from the first observation (S 0,62554273/W 90,38298825), recorded it on audio tape and filmed a short video sequence (tool J, Table 1). Tore Oldeide Elgvin, Kjetil Lysne Voje and Jens Ådne Rekkedal Haga from Oslo University observed another instance of blackberry tool use on February 21, 2010, in the upper Transition Zone near the village of Santa Rosa. This location is approximately 5 km away from the location described above. The observation was also recorded on video (tool I, Table 1) and one picture was taken (tool H, Table 1).

2.3. Measuring tool length

To determine the number and length of tools used, we coded 74 pictures and 4 screen shots from 3 video recordings but could only take length measurements from 27 of them. We used length, shape, colour, size and position of thorns, and timing information about when the picture was taken to categorize the tools. Tool length was measured by comparing it to the beak length of the bird holding the tool. We measured the length of the beak from the tip to the top of the nostril closest to the feathers which was usually the distance from the beak tip to the feather line. We measured the relative length of the tools to the beaks by superimposing straight lines onto both the beak and the tool in Microsoft PowerPoint and calculating the line lengths from the height and width information given in PowerPoint. Relative tool lengths were averaged across all observations of a particular tool and converted into millimetres by multiplying by the average beak length for the species. For average species beak length we used the average of 14 woodpecker finches we captured and measured from 2007 to 2008. Measurements of length were conducted by two independent raters. Inter observer reliability was high (Person's $r = 0.997$). To have an additional measure of reliability of this we used 2 pictures of laboratory experiments were the length of the tool was known (a dowel of 45 mm) and measured the length of the tool with the above mentioned method. These two measurements yielded a mean length of 46.6 mm.

Fig. 1. An adult woodpecker finch inserts a blackberry twig under the bark of a dead Scalesia tree.

We also compared the length of blackberry tools with the estimated length of tools made from native plants using unpublished data from a previous study (Tebbich et al., 2002). These data were collected between November 1996 and April 1997 in the Arid Zone of Santa Cruz Island. In this area woodpecker finches usually use twigs from native bushes (mainly *Croton Sculeris*) and trees (predominatly Palo Santo, *Bursera graveolens*) as tool material, but also from cactus spines (*Opunti*a *echios*, *Jasminocereus thouarsi*). The length of the tools was estimated in relation to mean beak length. However, we were not able to conduct a statistical comparison because observations of blackberry tool use were not independent (only a maximum of three individuals were observed, and most of these observations were made in a single tool use event) and tool lengths of tools from native plants were only estimated using the length of the beak as a reference.

3. Results

3.1. Behavioural observation

3.1.1. Transcript of the tape recording of behavioural observation: December 10, 2008, 11:00 am

An adult woodpecker finch broke off a twig from a blackberry bush, removed all leaves and inserted the blackberry twig upwards under the loose bark of the trunk of a dead Scalesia tree. The tool was twice as long as its own body (estimate) (see Fig. 1, tool B in Table 1). The bird dropped this tool and made another tool (tool C) from a blackberry twig and inserted it into the same crevice. It dropped this tool as well and made a third one (tool D) in the

Table 1
Tool ID and length information including the number of photographs or screen shots used to determine ID and length.

Tool ID	Number of photographs in which tool was identifiable	Number of photographs in which length could be measured	Length of tool (mm)
A	2	2	39.23
B	10	6	126.28
C	1	0	
D	10	6	122.04
E	3	1	100.25
F	2	2	55.72
G	4	4	82.58
H	1	1	44.29
I	Video	4	93.06
J	Video	5	48.49

same manner and of the same material as previously and inserted it at the same location. A juvenile woodpecker finch sat close by, facing the adult using tools. After about 20 min of inserting three different tools at the same location, the finch extracted a food item from under the bark. The food item was an egg sack of a spider. Both birds (juvenile and adult) flew off. After 90 s the juvenile returned and used a blackberry twig at the same location at which the adult had extracted the food item before (Fig. 2). The tool was very long and was later identified on pictures by its characteristic shape as the tools that the adult had dropped before (tool D). The juvenile moved up the tree trunk, with a tool in its beak. It then returned to the previous location, inserted it deeply under the bark, left it inserted for a few seconds and then took it out again. The adult approached the juvenile with a tool in its beak (tool E) and chased the juvenile away. The adult inserted its blackberry twig tool into the crevice while the juvenile sat on a higher branch, facing the adult and vocalizing (begging sounds). The adult continued to poke the slightly curved blackberry tool into the same crevice as before. The bird dropped this tool and took another tool from the ground which was longer and slightly curved (tool D, again identified on pictures). The juvenile was still sitting on the same tree. The adult inserted the tool deeply under the bark, and left it inserted (Fig. 3). It chased the juvenile away. The juvenile returned and followed the adult around. The juvenile returned to the dead trunk and used a very long tool – the same one that the adult had left in the crevice (tool D) – and inserted it under the bark, however, its movements were clumsy compared to the adult's. The juvenile held the tool sideways, moved to the back side of the branch and was out of sight for several seconds. When it re-appeared, the juvenile dropped the tool and ate an unidentified food item. It was not clear whether the food item was obtained with the help of the tool. The juvenile continued to hop along the trunk without a tool and found food under the bark. It held a very short tool (tool F) for 7 s, dropped it and continued to move along the trunk without a tool. The juvenile bird preened itself and was then out of sight for 20 s. The juvenile returned with a long blackberry tool (tool D). It inserted the tool into the same crevice as before, dropped the tool and searched for food without a tool. The bird picked up a tool (tool G), which was shorter than the previous one, and inserted it into the same crevice as before. The bird left the tool in the crevice, removed moss with its beak, took the tool out again and looked at us. It re-inserted the tool once more and then flew to the upper branch of a nearby tree with the tool in its beak, dropped the tool and moved along branches without a tool. We lost sight of the bird after approximately 28 min of observation.

Fig. 2. A juvenile woodpecker finch inserts a blackberry twig at the same location and with the same body posture as the adult.

Fig. 3. An adult woodpecker finch leaves the inserted twig in the crevice. The inserted twig ends at the upper toe of the bird.

3.1.2. Tape recording of behavioural observation: January 15, 2009, 8:43 am

An adult woodpecker finch stripped a blackberry twig off all of its leaves and broke off a piece of this twig. The resulting tool was 6–7 cm long (not on video tape and not included in Table 1). The bird poked the tool into holes. It looked as if the finch was inserting it, twisting the tool and making pulling movements, however, it could not be seen feeding. Subsequently the bird was filmed flying between trees holding a curved blackberry twig (tool I) but was soon lost from sight. The whole observation lasted approximately 2 min.

3.1.3. Video recording of behavioural observation made by members of the Oslo University, February 21, 2009

An adult woodpecker finch hoped onto a dead branch with a blackberry twig in its beak (tool J). It inserted the tool briefly into a tree hole. It hoped to the next tree hole and inspected it visually by turning its head and moving its eye close to the opening, but did not insert the tool. It then hopped onto another branch and searched the bark with the tool in its beak but without actually inserting the tool. The video sequence had a duration of 20 s.

3.2. Number, orientation and length of tools made from blackberry twigs

Nine distinct tools were identified from the photographs and video footage of the tool use. The tools ($N = 9$) ranged in length from 39 mm to 126 mm with a mean of 79.10 mm SD $\pm$33.55 mm). The number of photographs of each tool type and average lengths of each tool is given in Table 1. It was possible to measure the direction in which the thorns on the blackberry tools were facing in 37 of the 73 photographs. The thorns pointed back towards the bird in 36 cases and pointed outward in only one case (binomial test; $p < 0.0001$). In six tools out of nine tools both ends were clearly visible and in five of these, the “working tip” of the tool was thinner than the end that the bird held in its beak (binomial test, $p = 0.219$). One tool was equally thick at both ends, and it was impossible to measure the thickness of the tip for one tool.

3.3. Length of tools made from native plants

We observed 38 incidents of tool use and recorded tool type and length in 33 of these observations. Eighteen of these tools were cactus spines. Their length was limited by the natural length of cactus spines and ranged between 20 and 80 mm. All other tools were twigs of native bushes and their length ranged from 20 to 180 mm. Overall ($N = 33$), the mean ($\pm$SD) length of tools made from native plants was 52 ± 3 mm.

4. Discussion

On a mechanistic level, one of the main research questions concerning animal tool use is whether animals use tools in their functionally appropriate manner and whether they learn to do so by trial-and-error or rather by forming abstract representations of the underlying physical problems (i.e. contact, surface continuity) (Seed and Byrne, 2010). The evidence that tool using animals appreciate the functional features of tools is mixed (reviewed in Emery and Clayton, 2009; Seed and Byrne, 2010). In captivity one crow was observed to bend wire into functional hooks (Weir et al., 2002) but subsequent tests revealed that she did not consistently use them in a functional manner (Bluff et al., 2007). On the other hand rooks that normally do not use tools in the wild used hooks and bent wire into hooks and flipped them into the correct orientation (Bird and Emery, 2009). However, the same individuals seemed to lack an understanding of the necessity of contact in a tube task. In this task a dowel with a disc attached in the middle was inserted into a horizontal tube and a food reward was placed centrally left or right of the disc. The rooks learned to pull the disc from the correct side above chance in one configuration but failed in the transfer task (disc central condition) (Helme et al., 2006). Chimpanzees, the most proficient tool users in captivity and in the wild, show causal reasoning in some tasks but fail in others. For instance they are able to appreciate that objects will fall if moved across discontinuous surfaces (Mulcahy and Call, 2006; Seed et al., 2009) and like capuchins (Fujita et al., 2003) they learn about the functionality of tools in rake tasks (Povinelli, 2000) but fail in a range of other physical tasks that require to transfer knowledge to novel configurations (Povinelli, 2000).

The analysis of the pictures and video material of our own observations and those of others showed that woodpecker finches always held the blackberry twigs so that the barbs pointed backwards and were thus functional in the sense that the barbs could enhance the effectiveness of contact between tool and prey. For example, obtaining soft spider egg sacks, as we have observed woodpecker finches to do, might be easier with the help of barbs. However, the fact that woodpecker finches predominantly oriented the barbed twigs in a functional manner does not necessarily mean that they appreciate the function of the barbs. Holding the twigs in the correct orientation might be a consequence of the manufacturing process or the physical properties of the tool. New Caledonian crows make tools from the barbed edges of pandanus leaves (Hunt, 1996a) and usually use them in such a way that the barbs are pointing away from the working tip (Hunt and Gray, 2004b). However, experiments showed that crows do not consistently attend to the orientation of the barbs (Holzhaider et al., 2008). In their experiment Holzhaider et al. presented their study subjects with either a pandanus tool inserted into a baited hole with barbs pointing upwards (functional tool orientation) or downwards (non-functional tool orientation) and predicted that the crows would only flip non-functionally oriented tools. Along the same line they presented the crows with a choice between an intact pandanus tool and one with the barbs removed. The poor performance of the crows in both experiments indicated that they seem to lack an appreciation of the functional relevance of barbs (Holzhaider et al., 2008). The implication is that the manufacture process seems to be responsible for the correct orientation of pandanus tools in the wild: crows make the first cut at the proximal end of the leaf (near the trunk), followed by a rip along the fibre and make the last cut towards the distal end of the leaf. This usually results in grabbing the wider leaf base in the beak and thus the barbs automatically point away from the working tip (Holzhaider et al., 2008; Hunt and Gray, 2004b). Similarly we found that woodpecker finches predominantly handle blackberry twigs from the wide end using the thinner end as working tip which results in the barbs pointing backwards.

Another possibility is that woodpecker finches might learn the most efficient use of blackberry twigs by trial-and-error. Our previous studies have shown that woodpecker finches refine their tool using abilities during early ontogeny via trial-and-error learning (Tebbich et al., 2001) and that this ability enables them to solve novel tasks involving the use of tools (Tebbich and Bshary, 2004; Teschke et al., 2011; Teschke and Tebbich, 2011). However, we found no indication that they are able to appreciate the physical forces (dynamic mechanical interactions) that underlie the use of tools. For instance in a cane task woodpecker finches had to choose between two canes to obtain a food reward. One food reward was placed on the inside of the hooked portion of one of the canes (functional), while the other reward was located outside of the second cane’s hooked portion (non-functional). Eight out of 16 woodpecker finches learned to pull the correct cane within 149 trials, but they were not able to assess the problem in advance

(Teschke et al., 2011). Similarly some of them learned to avoid discontinuous surfaces that would trap food, but again, we found no evidence that they were able to appreciate the underlying physical problem (Tebbich and Bshary, 2004; Teschke and Tebbich, 2011). However, in experimental tests woodpecker finches were able to assess the necessary length of a tool for a specific task in advance: in the tool length task, food was presented at 4 different distances in a clear Perspex tube, and subjects were presented with tools of different lengths with which they could retrieve the food. Similar to New Caledonian crows (Chappell and Kacelnik, 2002), 3 out of 5 finches chose a tool of sufficient length at a level significantly above chance (Tebbich and Bshary, 2004). The blackberry twigs used in our first observation detailed here were very long compared to tools used in previous observations. It is therefore conceivable that the long tools were specifically tailored for a prey item that the adult bird suspected at a certain distance.

Tool modification of native plants has been previously observed in woodpecker finches. Particularly when woodpecker finches use twigs of native plants, they shorten them or break off side twigs that prevent insertion. In this species the systematic de-leafing of twigs has not been described before but removal of interfering twigs is probably based on a similar motor pattern. Experimental work supports the notion that trial-and-error learning is involved in acquiring the behaviour of removing side twigs. We presented adult woodpecker finches with H- and S-shaped tools which had to be modified by removing a transverse piece to make them suitable for the retrieval of food from a tube. Like several primate species (Visalberghi et al., 1995), 4 out of 6 woodpecker finches were able to solve the tasks, but like primates, they first inserted the unmodified tool before actually removing the transverse pieces and retrieving the food (Tebbich and Bshary, 2004).

Our observation that woodpecker finches use tools from an introduced plant with novel functional features provides further indication that they modify tools in a flexible manner and can make use of novel environmental opportunities. This trait has been regarded as a possible reason for the successful colonisation of the inhospitable Galápagos Islands and the subsequent radiation of Darwin's finches (Grant and Grant, 2008; Price, 2008; Tebbich et al., 2010). This species group has developed a whole suite of unusual behaviour patterns and use of food types that are highly unusual for passerines (Grant and Grant, 2008; Price, 2008; Tebbich et al., 2010). The ability to find new food types and novel ways of exploiting them has probably enabled them to colonise areas and islands with less favourable habitats which in turn set the stage for geographic isolation and subsequent speciation. But how did these new behaviour patterns emerge and spread? If they are the result of behavioural innovations from single individuals that are not heritable, they might disappear with the death of this individual, unless they are socially transmitted. We do not know the ontogenetic development of any of the foraging techniques of Darwin's finches described above, except tool use. This behaviour in woodpecker finches seems to be based on a very specific genetic predisposition and is refined by trial-and-error learning. Unlike chimpanzees (Nagell et al., 1993; Tomasello et al., 1987; Whiten et al., 1996) but similar to New Caledonian crows (Kenward et al., 2005, 2006) a social model is not necessary for the development of tool use in this species. Juvenile woodpecker finches that were raised without a tool-using model developed tool use in distinct developmental steps and at a similar speed compared to siblings who could watch a tool-using model during their ontogeny (Tebbich et al., 2001).

However, although this previous study demonstrated that social learning is not necessary for the development of tool use, it does not exclude the possibility that juveniles refine their tool use by observing details of how and where others use tools. Tools left in holes and crevices by proficient adults may facilitate this process. The situation of tools which have been abandoned in holes by adults and are subsequently used by juveniles has been reported for New Caledonian crows (Bluff et al., 2010) and now for woodpecker finches. The observation described here provides evidence that opportunities for the transmission of social information do occur in the wild.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.beproc.2011.10.016.

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