

REVISITING THE DEFINITION OF ANIMAL TOOL USE

ST. AMANT & HORTON: ANIMAL TOOL USE

ROBERT ST. AMANT and THOMAS E. HORTON
Department of Computer Science
North Carolina State University

Correspondence:

Robert St. Amant / Thomas E. Horton
Box 8206
North Carolina State University
Raleigh, NC 27695
US
stamant@csc.ncsu.edu, tehorton@unity.ncsu.edu

Word count: ~7,500 words (excluding abstract and references)

ABSTRACT

A definition of tool use due to Benjamin Beck has served the field of animal cognition well for over 25 years. This article proposes a new, more explanatory definition that accounts for tool use in terms of two complementary subcategories of behaviors: behaviors aimed at altering a target object by mechanical means and behaviors that mediate the flow of information between the tool user and the environment or other organisms in the environment. The conceptual foundation and implications of the new definition are contrasted with those of existing definitions, particularly Beck's. The new definition is informally evaluated with respect to a set of scenarios in which differences from Beck's definition and others in the literature can be seen.

Keywords: tool use, cognition

INTRODUCTION

Tool use has been one of the central concepts in animal cognition research for the past century. Studies of tool use, both in the laboratory and in the field, continue to advance our understanding of the behavioral and cognitive capabilities of animals today (Povinelli 2000; Tomasello & Call 1997). An important goal in understanding the nature of tool use is the development of a precise, comprehensive definition.

One of the earliest explicit definitions, due to van Lawick-Goodall, focuses on abstract properties of behavior, including functionality and goals:

[Tool use is] the use of an external object as a functional extension of mouth or beak, hand or claw, in the attainment of an immediate goal (van Lawick-Goodall 1970, p. 195).

Alcock's later definition is more detailed in its specification of goals as the alteration of form and position:

Tool-using involves the manipulation of an inanimate object, not internally manufactured, with the effect of improving the animal's efficiency in altering the form or position of some separate object (Alcock 1972, p. 464).

Beck (1980) offers a refinement of Alcock's definition, one that has come into wide use and is a current standard in the animal cognition literature:

Thus tool use is the external employment of an unattached environmental object to alter more efficiently the form, position, or condition of another object, another organism, or the user itself when the user holds or carries the tool during or just prior to use and is responsible for the proper and effective orientation of the tool (Beck 1980, p.10).

Various refinements and alternative definitions have been proposed since the publication of Beck's book (e.g., Chevalier-Skolnikoff 1990; Preston 1998; Lestel & Grundmann 1999; Matsuzawa 2001; Baber 2003; Catton et al. 2004; Holmes & Spence 2006), but his remains the most influential definition of tool use in the field. It is straightforward, robust in its application to specific cases, and a good match to the consensus judgments of experienced researchers in animal behavior. In this article, we analyze the criteria on which definitions of tool use are based, toward the development of a new definition of tool use. We use Beck's definition as an exemplar because of its generality and historical influence, though other definitions would also have been valid targets for comparison. The new definition matches that of Beck's for most cases in practice; we argue, however, that it offers a clearer account of why specific behaviors should be included or excluded. In those cases where the new definition does disagree with Beck's, we believe that the new classifications are credible and justified.

One might reasonably ask why a new definition is needed, given that Beck's existing definition has served the field of animal cognition for over 25 years and that later alternatives have not taken its place. We are partly motivated by recent popular attention to two examples of animal tool use. First, some dolphins wear marine sponges to protect their rostrums while probing for food on the ocean floor; some mother dolphins demonstrate to their female young how to use the sponges (Krützen et al. 2005). Second, tool use has been observed for the first time in gorillas in the wild; one gorilla used a stick to test the depth of water it was wading through (Breuer et al. 2005). While both of these behaviors are generally viewed as tool use, it is difficult to explain exactly why, in the terms set out in the definitions

above. A skeptic might argue that the dolphin's use of a sponge and the gorilla's use of a stick do not necessarily alter the form or position of other objects in the environment, and that explaining the behaviors in catch-all terms such as “functional extension of the mouth or hand” or “altering the condition of the tool user” is unacceptably vague. We believe that making the terms in a definition of tool use more precise, to the extent that this is possible, will reduce disagreements about their interpretation.

Another part of our motivation is based on our view that Beck's definition does not distinguish some contingent properties from necessary or causal properties of tool use. For example, object manipulation is central to tool use. In contrast, the “unattached” property of objects used as tools is not critical, even if it is present in most or even all observed cases of tool use in nature. Instead, this property arguably stands in for the degree of control that the animal can exert in manipulating an object as a tool; unattached objects are usable as tools, but being unattached *per se* is not a necessary property. Closer attention to the fundamental properties of behaviors that count as tool use should add clarity to their categorization. Further, such attention should help us understand why some behaviors are considered borderline rather than “true” tool use.

Last, we are motivated by the belief that advances in our understanding of tool use will have implications well beyond the fields of animal behavior and animal cognition. Insights from past research on animal tool use have already influenced the study of the evolution of cognition (Sterelny 2003), human neuropsychology (Maravita & Iriki 2004), human factors and human-computer interaction (Baber 2003), robotics (St. Amant & Wood 2005; Stoytchev 2005), and philosophy of mind (Clark 2002, Preston 1998). The range of topics covered by these fields gives us a further reason to study animal tool use, even if we eventually conclude that most relevant cases of animal behavior are analogous rather than homologous to human tool use. For example, if evolutionary or ecological considerations predict and explain a tool-using behavior in some species, rather than cognitive processing, this information may drive hypotheses about the evolution of tool use in our human ancestors; it may impose expectations on the behavior of a tool-using robot with limited processing capabilities; it may suggest promising areas for experimentation in neuroscience. Critical to all these avenues of research is a good definition of tool use.

Our discussion begins with an overview of concepts important to understanding tool use. Based on this discussion we move to a critique of Beck's definition of tool use, its weaknesses and strengths. We then propose a new definition, preserving the fundamental properties of Beck's definition, but extending it to encompass dynamic aspects of object manipulation and the use of tools to mediate the flow of information. Our discussion is driven by a set of scenarios that illustrate and motivate the new definition.¹

TOOL USE CONCEPTS

We begin by setting an informal target for a definition of tool use, as we understand the concept. A biological organism is separated from its environment by a physical boundary; for most animals and most behaviors, this boundary is approximately the surface of the skin. Interaction happens at the boundary in two ways: an organism can take action to cause physical alterations to the environment

¹ Length limitations prevent the inclusion of an empirical comparison of the new definition with Beck's in the body of this article, but an appendix explains how the new definition applies to three catalogs of animal behavior: a list due to Beck (1980) and two lists of behaviors from chimpanzee and orangutan material cultures (Whiten et al. 1999; van Schaik et al. 2003).

(e.g. pushing, crushing, or opening objects) and an organism can sense information in the environment (e.g. contact, resistance, or changes in light patterns).

The use of a tool mediates these interactions between the tool user and the environment. For a human familiar with a specific tool, it seems as if the boundary of the body is extended to encompass the tool, as if not just action but also sensing and sometimes communicative abilities have been transformed by the physical properties of the tool, an experience Clark (2002) describes in terms of “transparent equipment”.² Neurological studies of the brains of macaque monkeys engaged in tool using tasks (Iriki et al., 1996) have found evidence that such an integration of a tool into the user's internal representation of its own body does indeed occur, while Holmes and Spence (2004), using less invasive techniques, have found similar results in human studies.

In animal tool use, the physical aspects of mediation are easy to see: a chimpanzee might use its hand to strike a surface with some force; if the chimpanzee strikes with a stone in its hand, the force is amplified. An orangutan might reach into a hole with its finger; a stick held in its hand will reach farther or into narrower openings. Just as importantly, sensory input, in particular tactile input, is mediated at the same time. The chimpanzee can sense the greater momentum of its arm and the greater impact of the stone on the surface. The orangutan can sense when the stick reaches the bottom of a hole or is blocked by some object or organism, even if it cannot see the point of contact. (We have no first-person reports, of course, but we can infer such sensing ability based on our knowledge of physics and physiology.) As Iriki et al. (1996, p.2325) put it, “A tool is an extension of the hand in both a physical and a perceptual sense.”

Mediation of sensory input is not the only role tools can play with respect to information. Noble (1998) defines animal communication in terms of “influence interactions”, in which one organism influences the way that another organism perceives the environment, resulting in a change in the latter's behavior. Tools can be used to create and mediate influence interactions: a brandished stick might communicate a more effective threat than a bare fist, for example; a bunch of leaves might amplify noises made with the mouth. In such situations, tools can be thought of as mediating information flow between organisms.

BECK'S DEFINITION: A CRITIQUE

None of the preceding summary should be controversial. Perhaps surprisingly however, existing definitions, including Beck's, generally focus on the physical aspects, leaving sensory and communication-related issues implicit (a subject we visit in detail in a later section). Even within the scope of physical interaction, Beck's definition raises subtle questions when applied to some cases of tool use: first is the criterion that tools be unattached objects; second is the specification of the “condition” of objects and organisms that tools modify; third is the specification that the use of a tool results in an alteration of the environment. We discuss each of these points in turn.

Unattached Objects

Beck gives an example of a rat that receives a reward by pressing a lever in a Skinner box, but excludes this case from tool use because the lever is not carried by the rat or free of the environmental substrate

² Tool use is the tip of an iceberg in the philosophy of mind literature; closely related to tool use is the concept of the “extended mind”, which considers the extension of cognitive processing beyond the bounds of the body (Clark & Chalmers 1998).

(Beck 1980, p.8). This is a plausible solution, but it captures what we think of as a contingent rather than necessary property of objects used as tools. Consider the following scenarios, which deal with experimental apparatus developed, at least hypothetically, for testing problem-solving abilities.

Scenario 1a: A string, anchored to the rim of a transparent tube, hangs down in the interior of the tube, with an otherwise inaccessible reward attached to its end. A bird (e.g. a raven (Emery 2006)) pulls up the string to retrieve the reward.

Scenario 1b: At the bottom of a transparent tube sits a reward in a small bucket with a loop handle. A bird (e.g. a Caledonian crow (Weir et al. 2002)) finds or fashions a hook, dips it into the tube, catches the handle with the hook, and pulls up the bucket holding the reward.

Scenario 1c: In a variation of the apparatus of scenario 1a, the anchored string has a hook rather than a reward at its end. A bucket sits in the bottom of the tube, as in scenario 1b. A bird grasps the string, swings the hook at its end such that it catches the handle, and pulls up the bucket holding the reward.

Beck categorizes scenario 1a as not being tool use (Beck 1980, p. 8), by analogy to a monkey that pulls up a vine to retrieve fruit growing at its end, observing that the string, like the vine, is attached to the substrate. Scenario 1b is clearly categorized as tool use. Unfortunately, scenario 1c is excluded by Beck's definition for that same reason as scenario 1a: the bird is manipulating an object, an anchored length of string, that is attached to the substrate. This does not match our intuitions, however. Beck's definition gives us no easy way to distinguish between the hook-tied-to-a-string and the reward-tied-to-a-string, and yet we would like to treat the former as tool use, the latter not.

Part of the problem in these two scenarios is deciding what constitutes an object. In simple cases, the property of being unattached from the environmental substrate is sufficient to define an object, but in other cases this poses problems, such as deciding whether some composition of materials should be treated as a single object or multiple objects. This turns out to be a difficult ontological issue in philosophy, and we do not address it here.

Taking an alternative approach, it seems reasonable to interpret the unattached property of objects in Beck's definition as standing in for the degree of control that the animal exerts over objects used as tools (a point we discuss in more detail in a later section). That is, an unattached object may be freely manipulable while the same object, if attached to the substrate, is not. Such manipulability of an object is a more informative indicator of tool use than whether the object is unattached. Thus, scenario 1c should be considered tool use because the hook is freely manipulated in its use.

One property of tools related to being unattached may be useful to retain: tools are generally discrete objects rather than amorphous materials. Given our discussion above, we can argue that water, sand, and free-flowing mud are usually inappropriate materials for tool use because it is not usually possible to manipulate them as objects. Consider the following examples:

Scenario 2a: An archer fish projects water droplets to knock its prey (insects and spiders) off their perch onto the surface of the water (Alcock 1972).

Scenario 2b: An elephant sprays water from its trunk onto its back to cool off (Beck 1980).

Scenario 2c: A chimpanzee cups water in its hand and splashes its body to cool off.

Beck counts scenarios 2a and 2b as tool use. Few would describe scenario 2c as tool use, however, though it arguably meets the letter of Beck's definition in the same way as scenario 2b. The discreteness of the material being used, though an ambiguous criterion, gives us a possible way to distinguish the scenarios. To the extent that water retains a specific form or shape in its use, it may be plausibly (though not universally) described as a tool.

The Condition of Objects

Beck extends Alcock's definition to include the “condition” of an object or organism that may be altered, to capture such behaviors as self-maintenance with tools. The generality of conditions raises difficulties, though. Consider the following hypothetical scenario:

Scenario 3: A chimpanzee finds a hat accidentally discarded by a field researcher. The chimpanzee places the hat on its head.

Few would count scenario 3 as tool use, and yet it arguably meets the letter of Beck's definition. The chimpanzee is responsible for effectively orienting and placing the hat on its head, in order to alter its own state: it now meets the condition “having a hat on its head”, or perhaps even “looking foolish”. We might make a similar argument about birds adding twigs to their nests being tool users, in that the “structural stability” condition of the nest is altered, but the point should be clear: given a sufficiently broad interpretation of conditions, holding, moving, and placing any unattached object can be viewed as tool use by Beck's definition. We would like to rule out such behaviors. A plausible resolution of this problem is to view tool use in terms of dynamic, mechanical interactions rather than alteration of general conditions. That is, scenario 3 is not tool use because the actions of the organism do no more than establish static spatial relationships rather than produce dynamic interactions between the candidate tool and the environment. We discuss this point in further detail in a later section.

Alteration of the Environment

Finally, Beck's definition describes the alteration of the environment by a tool. Consider three scenarios that test this criterion.

Scenario 4a: An Egyptian vulture drops a stone onto an egg, repeatedly, until the egg is cracked open (Panger 1998).

Scenario 4b: An Egyptian vulture drops a stone onto an egg, but the impact is not sufficient to crack the egg. Before the vulture can repeat its action, it is frightened away by an intruder.

Scenario 4c: An Egyptian vulture drops a stone onto an egg but misses. Before the vulture can repeat its action, it is frightened away by an intruder.

Scenario 4a is generally recognized as tool use. Because the behaviors in the remaining scenarios do not reach a successful conclusion, however, they cannot be said to alter the environment. To accommodate these scenarios, we can interpret “the use of an object to...” as implying a goal to be achieved. While Beck explicitly rules out consideration of cognitive processes, inferring the existence of a goal or incentive is commonplace in his work and elsewhere; another way to express this idea is that a tool performs a function.

We can nevertheless remove some of the ambiguity of interpretations of these scenarios, as with those previously described, if we shift our focus away from the effect of a behavior to the dynamics of the physical interaction. That is, when Beck's definition specifies that tool use requires “the proper and effective orientation of the tool”, we automatically fill in a dynamic, mechanical account that enables us to interpret these criteria appropriately. This shift is enough to capture our intuitions about these scenarios: in each case, the behavior involves manipulating or dropping an object to generate an impact on a target. When the impact is insufficient to crack the target, we count the behavior qualitatively as tool use; even if the target is missed, the goal of producing the impact is apparent.

While we find a few aspects of Beck's definition potentially problematic—unattached objects, the conditions of objects, and alteration of the environment—there remain two fundamental aspects of tool use that we wish to retain when formulating a new definition: the importance of goals (as briefly discussed above) and deliberate control over objects in the environment.

Goals in Tool Use

Tool use is commonly described as goal-directed behavior (Ingmanson 1996), reflecting a common view of actions in general in the cognitive science literature. Another important property of actions is that they are schematic, with roles that can be played by objects or properties of the environment (Matsuzawa 2001). The action of reaching for an object, for example, is not entirely captured by a description of motor behavior; instead, a description must refer to the object in its role as the target of the reaching action. We can see this aspect of tool use in the structure of Beck's definition: an animal takes some action *in order to* achieve some effect.

Actions and goals can have subtle relationships in the context of tool use. It is not sufficient simply to assign objects to roles in specific actions and call the behavior tool use. To see why, imagine an animal pounding an object onto the ground. When the animal stops, the object is unchanged, but the ground has been flattened in the area under the pounding. Is this tool use or not? This behavior generalizes two familiar scenarios from the tool use literature, one viewed as tool use, the other not.

Scenario 5a: A wasp pounds a pebble onto the ground (Oswalt 1973). When the wasp stops, the pebble remains unchanged, but the ground has been compacted and flattened around the opening to its nest.

Scenario 5b: A chimpanzee pounds a nut held in its hand onto the ground (Inoue-Nakamura & Matsuzawa 1997). When the chimpanzee stops, the nut remains unopened, but the ground has been flattened, as an incidental effect, in the area of its pounding activity.

Clearly, not enough information is given in the general description to distinguish between scenarios 5a and 5b as tool use. A natural way to distinguish the two is in terms of differing goals. In scenario 5a, the goal of the wasp is to flatten the earth around its nest; in scenario 5b, the goal of the chimpanzee is to break open the nut. Further, the actions in these cases are characterized differently with respect to the roles objects play. In the case of the wasp, the tool is the pebble and the target the surface of the ground; in the case of the chimpanzee, the target is the nut and there is no tool. Even in cases where the physics of the interaction between objects may be identical at some level of abstraction (an impact between an object and a surface), our understanding of the goals of a behavior makes a difference in our interpretation. In brief, a behavior or action is described in terms of the roles played by specific objects and its effect; if the object meets certain constraints and the effect matches a given goal, the behavior is viewed as tool use.

Control in Tool Use

In a discussion of capuchin tool use, Panger (1998) observes that branch dropping is so common a behavior in some primate species that it is difficult to judge, given widely varying contexts, whether it meets Beck's definition. This can be seen as an issue of assigning appropriate goals to behaviors, but another issue comes into play: what counts as responsibility (an explicit term in Beck's definition) for achieving a goal? Let's consider a few examples:

Scenario 6a: A monkey flees through the canopy, dislodging branches that discourage potential followers (Beck 1980).

Scenario 6b: A chimpanzee uses a stone as a hammer to open a nut (Whiten et al. 1999); at some point during the process, the stone slips from the chimpanzee's grasp but nevertheless strikes the nut.

Scenario 6c: A heron scatters bits of biscuits on the water to attract fish it can then catch (Beck 1980).

Scenario 6d: A chimpanzee throws a stone against a hard surface to remove flakes, in a stone tool manufacturing context (Byrne 2004).

Beck's definition specifies that an animal must be responsible for its tool-using behavior, to eliminate accidental or incidental achievement of goals. The scenarios above show that determining responsibility for action, in terms of control, may not be straightforward. Scenario 6a is clearly not tool use. It would be difficult however, to argue that scenario 6b is not tool use, even if the degree of control is less than if the stone hammer had not slipped. Scenario 6c is more ambiguous. Under what circumstances should a scattering action under only loose directional control be considered tool use? In analogous human behavior, someone might scatter birdseed or crumbs of bread on the ground in a park to attract birds; a hunter might place a salt lick in the woods to attract deer. Such activities establish an incentive for the behavior of animals, but we generally do not view the activities as human tool use. Finally, scenario 6d is a striking example of tool manufacture but it is not specifically described as tool use in itself. We believe that this is not simply an oversight but is based on two justifications: the stone hammer being created is the target of the behavior, rather than a tool, and the loose control over the action is inconsistent with other cases of tool use.

We can see the differing categorizations of these examples as falling along a continuum of control. In Beck's definition, the control component of tool use falls under a binary criterion: is the candidate tool user responsible for the orientation of the external object or not? We believe that this is overly restrictive, that the degree of control an animal applies to a candidate tool object influences the categorization of a behavior as tool use or not. As interactions move from being accidental to incidental to controlled, a behavior approaches the category of tool use.

A NEW DEFINITION OF TOOL USE

At this point, we have introduced a set of concepts sufficient to suggest a new definition of tool use:

Tool use is the exertion of control over a freely manipulable external object (the tool) with the goal of [1] altering the physical properties of another object, substance, surface, or medium (the

target, which may be the tool user or another organism) via a dynamic mechanical interaction, or [2] mediating the flow of information between the tool user and the environment or other organisms in the environment.

The issues of control, manipulability, and goals have already been covered, but the new definition identifies two classes of behavior: those associated with altering a target by some dynamic interaction, and those associated with the transmission or mediation of information. Before discussing these classes in more detail, it will be worthwhile to revisit our scenarios to see how they fare under the new definition.

For scenarios 1a (an anchored string attached to a reward), 1b (a free hook), and 1c (an anchored hook), the criterion of free manipulability produces categorizations that match our intuitions, improving on Beck's criterion of unattached objects as tools. While the new definition disagrees with Beck's on scenario 1c by classifying it as tool use, this classification is justified. Interpretation of scenarios 2a through 2c depends on whether we consider water droplets, a water stream, or a splash of water to be discrete objects. The new definition produces no difference from Beck's definition. Scenario 3, potentially tool use under Beck's definition, is not tool use under the new definition: the placement of a hat on a head involves the establishment of a static relationship rather than a dynamic mechanical interaction. The new definition removes ambiguity associated with the conditions of objects. Scenarios 4a through 4c, which deal with unsuccessful egg-cracking, are tool use under the new definition, as is the case with a slightly broadened interpretation of Beck's. Again, the improvement is subtle but clear, in that goals are explicitly accommodated, even if they are not achieved by a given behavior. Scenarios 5a (a wasp pounding with a pebble) and 5b (a chimpanzee pounding with a nut) are distinguished by different assignments of objects to tool and target, as with Beck's definition. For scenarios 6a through 6d, which deal with control, the analysis also does not differ significantly from Beck's except in the case of 6c, involving a scattering of objects. We believe that a consideration of control, rather than the more abstract concept of responsibility, adds a worthwhile feature to the new definition of tool use.

It might be argued that the new definition introduces unobservable properties of behavior that must be inferred, making interpretation more ambiguous. We would respond that while “control” and “goals” must be evaluated by an observer, they are to some extent already implicit in the “responsibility” criterion and the “in order to” structure of Beck's definition. Further, the ambiguity of interpreting efficiency, conditions, and proper/effective actions in Beck's definition is eliminated in the new definition.

In the remainder of this section we describe the two novel aspects of the new definition that deal with dynamic interactions and information mediation, the latter with respect to both sensory input and communication. We then briefly discuss the larger scope of behavior in which tool use takes place, to identify potential limitations of the new definition.

Dynamic Mechanical Interactions

In our earlier discussion of the conditions and environment alteration identified in Beck's definition, we proposed that dynamic mechanical interactions provide a more appropriate focus for a definition of tool use. The key idea is that in the most familiar examples of tool use—pounding with a stone, probing with a twig, transporting liquid with a leaf sponge, levering with a sturdy stick—an effect is generated by the dynamic mechanical interaction between the manipulated tool and other objects or organisms in the environment. The tool may allow the user to perform interactions of which it would otherwise be

incapable, or simply make interaction easier or more effective. The interaction may be as simple as contact, but it may be complex, as in the case of termite fishing, in which termites bite a long blade of grass and are extracted from their nest before they can disengage themselves. In general, by this criterion we mean to eliminate the establishment of static relationships between objects or the tool user as being the only result of tool use: building nests, placing a stone in a specific location (even if this aids tool use (Matsuzawa 2001)), stacking boxes, and so forth. We return to these examples below to justify this distinction.

One advantage of focusing on interaction rather than end effects is that it can simplify description of some behaviors. For example, orangutans have been observed using sticks to scratch body parts. It is easy to describe the contact between the stick and the skin as a physical interaction. In contrast, describing the effect of this tool-using behavior poses problems: following Beck's definition, some condition of the orangutan has been altered (the presence of an itch, presumably), information that is available to us only by inference. The interaction is directly observable, at least in principle, and thus a more appropriate target for description.

An interesting and slightly controversial case deals with throwing and dropping behaviors. There is some disagreement about their status; for example, Ingmanson (1996) categorizes dropping objects as “tool-related” behavior rather than tool use. Thrown or intentionally dropped objects are easily dealt with as tools in Beck’s definition, in that they are held just prior to use. The new definition agrees with Beck: thrown or dropped objects are tools when they are freely manipulable, their trajectory is under the control of the tool user, and the goal is to produce a mechanical interaction. (That is, an object tossed randomly into the air would not be treated as a tool.)

Information Flow: Mediating Sensory Input

While we generally think of tools as being used to alter the environment, this is not the only possibility. Let's revisit an example from the introduction:

Scenario 7: A gorilla uses a stick to test the depth of water it is wading through (Breuer et al. 2005).

In this scenario, we have no relevant alteration of the environment, but there is a physical interaction that extends the sensory capabilities of the gorilla. Such cases can be handled by Beck's definition, but only if we view inferred modifications to the internal state of the tool user as alteration of their “condition” - this broad interpretation opens the door to other behaviors that are not plausibly tool use, as discussed earlier. If we consider the mediation of sensory input as one possible function of tools, as in the new definition, this ambiguity is removed. We can further extend the concept of sensory mediation with another example from the introduction:

Scenario 8: A dolphin picks up a marine sponge and uses it as a glove on its rostrum during foraging (Krützen et al. 2005). The dolphin encounters no stinging animals or sharp surfaces while foraging.

Scenario 8 has been widely described as tool use in both the technical literature and the popular press. To the extent that the glove may aid in foraging (currently an open inference), it can be considered a tool: it changes the dynamics of the mechanical interaction between the dolphin's rostrum and foraging surfaces. However, even if the environment is not significantly altered by the use of the glove (e.g., if it is used only for probing, as with the gorilla's stick), it should still be considered tool

use under the new definition because of the glove's mediation of sensory input. One conceptual implication that may not be immediately apparent is that the sensory mediation that a glove provides is not necessarily with respect to a specific information signal; in scenario 8, the dolphin encounters no actual harmful sensory stimuli. Nevertheless the glove does mediate sensory input in general, by its reduction of sensitivity to environmental features, and it is straightforward to argue that the goal of using the glove is to avoid potential painful stimuli.

Information Flow: Mediating Communication

Some behaviors involving the interaction between organisms seem to be unambiguously tool use, yet fitting them into existing definitions turns out to be surprisingly difficult. For example, Beck describes a gorilla tearing up and brandishing a sapling to discourage an intruder (Beck 1980). This is categorized as tool use, presumably because the condition of the intruder (e.g., location) is altered by the behavior of the gorilla. But this is not the only outcome possible. In response to the gorilla's behavior, an intruder, though discouraged from approaching, may decide not to retreat but to remain in its location. How are we then to identify discouragement? We might seek a reliable, species-independent indication of discouragement general across aggressors and treat it as a condition, but this seems a hopeless task. Even less promising is the imputation of an unobservable "discouragement" condition to intruders.

In the new definition, these issues are addressed by adopting the concept of influence interactions from the animal communication literature (Noble 1998), as mentioned above. Explicating Noble's conceptual framework in detail is beyond the scope of this article; briefly, however, we treat what an organism perceives in the environment as information. Under the new definition of tool use, when another organism controls a freely manipulable object to mediate the information perceived by another organism (i.e., to mediate or produce an influence interaction), this is tool use. This accounts for the gorilla brandishing a sapling and related cases (e.g., an adult macaque brandishing an infant to discourage a conspecific aggressor (Beck 1980), in which the infant is used as if it were an inanimate object).

As with other types of tool use, a few potentially ambiguous scenarios are worth discussing in more detail.

Scenario 9a: A chimpanzee shakes a branch to attract attention or to court (Whiten et al. 1999).

Scenario 9b: A chimpanzee strips leaves off a stem, as a threat (Whiten et al. 1999).

Scenario 9c: An orangutan drags a branch on the ground as a display (van Schaik et al. 2003).

Scenario 9d: An orangutan hides from humans or predators behind a detached branch (van Schaik et al. 2003).

All of these behaviors are classified as tool use under the new definition, based on a first assumption that the objects involved are freely manipulable and a second assumption that the behaviors can be interpreted as influence interactions. We include scenario 9d to show that tool use for mediating information flow between organisms is not identical with tool use for communication, as in scenarios 9a through 9c. In 9d, the goal is deception rather than communication. Under the assumption that the detached branch is held by the orangutan, however, the behavior is still tool use because of the information-mediating function of the branch as a tool.

We note that the new definition does not encompass some behaviors described as social tool use, a set of behaviors that can be informally described as involving one animal interacting with a second animal to influence the behavior of a third animal (Kummer 1967). Johnson and Oswald (2001) break down social tool use into five categories: recruitment, agonistic buffering, passport, incitement, and alibi. While there are a few connections between social tool use and animal material culture, it is not yet clear to us that these types of behaviors can (or should) be fit into the same general category as the tool-using scenarios we have discussed throughout this paper. Cataloguing such connections and integrating the results remain for future work.

The Context of Tool-Using Actions

Finally, we must address the limitations of the new definition in a different direction, related to broader patterns of behavior in which tool use occurs. Some behaviors categorized in the literature as tool use are excluded by the new definition, with two prominent cases being the following:

Scenario 10a: A chimpanzee stacks two boxes to retrieve a piece of fruit (Beck 1980).

Scenario 10b: A chimpanzee wedges a stone under another stone to use as an anvil. The chimpanzee places a nut on the anvil and then cracks it open with a stone hammer (Matsuzawa 2001).

Beck describes scenario 10a as tool use, though the stack of boxes is not carried before it is used, arguing that if a single box were carried and used for climbing, the behavior would be captured by his definition and that it would be inconsistent to exclude a more sophisticated example of the same behavior. In Matsuzawa's scenario, reproduced here as 10b, the wedge and the anvil are described as metatools (Matsuzawa 1991). Matsuzawa identifies both the placement of the wedge under the anvil and the striking of the nut as tool use.

The new definition is more restrictive for both scenarios: 10a is not tool use, and only the action of striking the nut in 10b is tool use. While this is a clear result of the new definition, the more interesting question is whether the conflict with widely accepted interpretations is justified.

Scenario 10a does not match the general pattern of other tool-using behaviors in two ways. First, it is easily decomposed into two distinct behaviors, stacking and climbing, neither of which alone is tool use. Other behaviors described as tool use involve a single repeatable action (e.g., striking, reaching, dropping) or a complementary pair of actions (e.g., inserting and removing, in termite fishing or using a leaf sponge). To see why this poses a conceptual difficulty, imagine inserting a long delay between the stacking and the climbing actions in 10a. Beck's definition then rules out the behavior as tool use—the last box is not held just prior to use—but this modification to the scenario does not strike us as a change that should be significant. Second, the identity of the target or object of the tool (the box being the tool in this scenario) is unclear. Is it the reward? But the position or condition of the reward is not directly altered by the box. Is it instead the chimpanzee, acting simultaneously as a tool user and an object whose position is now altered? We must then explain why analogous activities such as mound-building, which enable some animals to reach a more elevated position, are not tool use. It may be possible to fit scenario 10a into a concept of tool use, but we are aware of no existing definition that provides an adequate explanation why.

Matsuzawa describes scenario 10b in terms of a tree-structure analysis, based on a simple definition

of tool use (Matsuzawa 2001, p. 14): "The essence of tool use is to relate one thing (the tool) to another (the target)." His tree-structure analysis organizes relationships between objects into a hierarchy that represents the sophistication (or cognitive complexity) of a tool behavior. Only object relationships are included in the analysis, with the tool user and actions being eliminated from consideration. Thus the establishment of the static relationship between the wedge and the anvil constitutes tool use in Matsuzawa's view, as does the striking of the nut. We note that the relationships in Matsuzawa's definition, like the conditions in Beck's definition, are overly broad, failing to eliminate clear examples of non-tool use. The more important issue, however, is whether the establishment of static relationships via metatools should be considered tool use rather than being excluded by the new definition.

We argue that establishing static relationships and producing dynamic interactions are conceptually distinct activities in the context of tool use. One simple difference, implicit in our previous discussion, is that dynamic mechanical interactions are those that lead to an immediate reward; they are not just the last action taken in some sequence, but rather the critical action that causes a desired result. Consider an analogy in human tool use: a carpenter clamps a piece of work between two lengths of scrap wood to avoid dents; he wraps a sheet of sandpaper around a wooden block; he dons a pair of goggles; and then, when all is ready, he begins to sand. All but the sanding actions can be thought of as preparing the environment to improve its suitability for tool use. Scenario 10b has the same structure as our analogy, with metatool use playing an auxiliary, preparatory role in the behavior. (Tool manufacture fits naturally into this description: it involves the fashioning or modification of objects in the environment to improve their suitability as tools.) We believe that tool use can be distinguished from metatool use in the same way that tools are distinguished from metatools. That said, it should be possible to fit the new definition of tool use into Matsuzawa's analysis, to provide a broader conception of tool use over sequences of behaviors: the use of metatools for environment modification, in support of the dynamic mechanical interactions of tool use. As with our consideration of social tools, however, this remains for future work.

CONCLUSION

We have presented a new definition of tool use and argued that it improves on the standard definition in the literature. It explicitly encompasses two general classes of behavior: those that produce dynamic interactions with the environment, and those associated with mediation of the flow of information in the environment. The new definition is not perfect. An important caveat identified by Beck (1980, p. 133) is that tool use "dovetails imperceptibly with other categories of behavior." In other words, tool use arguably does not constitute a distinct category of behaviors (Preston 1998). This can be seen in the issues discussed in previous sections: objects used in a tool-like fashion may not be unambiguously discrete; control may vary between different cases of the manipulation of a candidate tool object; there may be reasonable disagreements about the inferred goals of a given behavior. The new definition can perhaps best be viewed as a description of properties of behavior that are centrally associated with tool use. We believe it provides a more explanatory account of tool-using behavior.

One of our motivations was to provide a more precise set of criteria by which behaviors can be categorized. The new definition provides such added precision. We consider control rather than responsibility, and we evaluate dynamic interactions rather than alteration to conditions, among more minor changes. The resulting categorizations of behavior are largely in accord with existing definitions, but we believe they now have a better-understood justification.

Another of our motivations was to extend existing definitions to behaviors that are difficult to account for as tool use. These fall into two classes: tools used to extend the sensory capabilities of a tool user,

and tools used for communication and related interaction with other organisms. We believe that these behaviors are largely unaddressed by existing definitions but are properly handled by the new definition, which constitutes an advance in our understanding of tool use.

Our last motivation, generality, can be interpreted in part by asking the question, “How important is a new definition to the study of animal behavior?” One might argue that having a clear definition of tool use has become an irrelevant issue, that tool use is subsumed by the more general concept of material culture, in which making fine distinctions between different ways of using objects is less critical. Yet some of the issues covered in this article apply equally well to the broader subject: patterns of object use, goal-directed behavior, abstract categories of behavior, and even what should be treated as an object. In other words, we pursue the best possible definition of tool use in part for the promise that it might help us better understand other issues in animal cognition. In a related field, animal communication, McGregor (2005, p. 4) summarizes one result as follows:

So a problem arising from definitions has given real insight, rather than the acrimonious defence of definitions that is all too common in the literature.

Similarly, we hope that a refined definition of tool use will lead to new insights into the nature of the subject and its relationships to other fields.

REFERENCES

- Alcock, J. 1972. The evolution of the use of tools by feeding animals. *Evolution*, 26, 464–473.
- Baber, C. 2003. *Cognition and Tool Use: Forms of Engagement in Human and Animal Use of Tools*. Taylor and Francis.
- Beck, B. B. 1980. *Animal Tool Behavior: The Use and Manufacture of Tools*. Garland Press, New York, NY.
- Breuer, T., Ndoundou-Hockemba, M., & Fishlock, V. 2005. First observation of tool use in wild gorillas. *PLoS Biology*, 3 (11), 2041–2043.
- Byrne, R. 2004. The manual skills and cognition that lie behind hominid tool use. In Russon, A. E., & Begun, D. R. (Eds.), *Evolutionary origins of great ape intelligence*. Cambridge University Press.
- Catton, C., Dalton, R., Wilson, C., & Shotton, D. M. 2004. *SABO: A draft standard animal behaviour ontology*. Unpublished manuscript. http://www.bioimage.org/pub/SABO/SABO_cornell_final.pdf.
- Chevalier-Skolnikoff, S. 1990. Tool use by wild *cebus* monkeys at Santa Rosa National Park, Costa Rica. *Primates*, 31 (3), 375–383.
- Clark, A. 2002. Minds, brains and tools. In Clapin, H. (Ed.), *Philosophy of Mental Representation*. Clarendon Press.
- Clark, A., & Chalmers, D. 1998. The extended mind. *Analysis*, 58, 10–23.
- Emery, N. J. 2006. Cognitive ornithology: the evolution of avian intelligence. *Philosophical Transactions of the Royal Society B*, 361, 23–43.

- Holmes, N. P., & Spence, C. 2004. The body schema and multisensory representation(s) of peripersonal space. *Cognitive Processing*, 5, 94–105.
- Holmes, N. P., & Spence, C. 2006. Beyond the body schema: Visual, prosthetic, and technological contributions to bodily perception and awareness. In Knoblich, G., Thornton, I., Grosjean, M., & Shiffrar, M. (Eds.), *Human body perception from the inside out*, pp. 15–64. Oxford University Press, Oxford.
- Ingmanson, E. J. 1996. Tool-using behavior in wild *pan paniscus*: Social and ecological considerations. In Russon, A. E., Bard, K. A., & Parker, S. T. (Eds.), *Reaching into Thought: The minds of the great apes*, chap. 9, pp. 190–210. Cambridge University Press, Cambridge, UK.
- Inoue-Nakamura, N. & Matsuzawa, T. 1997. Development of stone tool use by wild chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology*, 111, 159-173.
- Iriki, A., Tanaka, M., & Iwamura, Y. 1996. Coding of modified body schema during tool use by macaque postcentral neurons. *Neuroreport*, 7, 2325–2330.
- Krützen, M., Mann, J., Heithaus, M. R., Connor, R. C., Bejder, L., & Sherwin, W. B. 2005. Cultural transmission of tool use in bottlenose dolphins. *Proceedings of the National Academy of Sciences*, 102 (25), 8939–8943.
- Kummer, H. 1967. Tripartite relations in *Hamadryas* baboons. In Altmann, S.A. (Ed.), *Social Communication Among Primates*, p. 63-71. University of Chicago Press, Chicago.
- Lestel, D., & Grundmann, E. 1999. Tools, techniques and animals: the role of mediations of actions in the dynamics of social behaviours. *Social Science Information*, 38 (3), 367–407.
- Maravita, A., & Iriki, A. 2004. Tools for the body (schema). *Trends in Cognitive Sciences*, 8 (2), 79–86.
- Matsuzawa, T. 1991. Nesting cups and metatools in chimpanzees. *Behavioural and Brain Sciences*, 14, 570-571.
- Matsuzawa, T. 2001. Primate Foundations of Human Intelligence: A View of Tool Use in Nonhuman Primates and Fossil Hominids. In Matsuzawa, T. (Ed.), *Primate Origins of Human Cognition and Behavior*, pp. 1-25. Springer-Verlag, Tokyo.
- McGregor, P. K. (Ed.). 2005. *Animal Communication Networks*. Cambridge University Press.
- Noble, J. 1998. *The Evolution of Animal Communication Systems: Questions of Function Examined through Simulation*. D. phil., University of Sussex.
- Oswalt, W. H. 1973. *Habitat and Technology: The Evolution of Hunting*. Holt, Rinehart, & Winston, New York, NY.
- Panger, M. A. 1998. Object-use in free-ranging white-faced capuchins (*cebus capucinus*) in Costa Rica. *American Journal of Physical Anthropology*, 106, 311–321.

- Povinelli, D. 2000. *Folk Physics for Apes*. Oxford University Press, NY.
- Preston, B. 1998. Cognition and tool use. *Mind and Language*, 13 (4), 513–547.
- St. Amant, R., & Wood, A. B. 2005. Tool use for autonomous agents. In *Proceedings of the National Conference on Artificial Intelligence*, pp. 184–189 Menlo Park, CA. AAAI Press.
- Sterelny, K. 2003. *Thought in a Hostile World: The Evolution of Human Cognition*. Blackwell Publishers, Oxford.
- Stoytchev, A. 2005. Behavior-grounded representation of tool affordances. In *IEEE International Conference on Robotics and Automation (ICRA)*.
- Tomasello, M., & Call, J. 1997. *Primate Cognition*. Oxford University Press, New York, NY.
- van Lawick-Goodall, J. 1970. Tool-using in primates and other vertebrates. In Lehrman, D., Hinde, R., & Shaw, E. (Eds.), *Advances in the Study of Behavior*, Vol. 3, pp. 195–249. Academic Press, New York.
- van Schaik, C. P., Ancrenaz, M., Borgen, G., Galdikas, B., Knott, C. D., Singleton, I., Suzuki, A., Utami, S. S., & Merrill, M. 2003. Orangutan Cultures and the Evolution of Material Culture. *Science*, 299 (5603), 102–105.
- Weir, A. A. S., Chappell, J. and Kacelnik, A., 2002. Shaping of hooks in New Caledonian crows. *Science* 297, 981.
- Whiten, A., Goodall, J., McGrew, W. C., Nishida, T., Reynolds, V., Sugiyama, Y., Tutin, C. E. G., Wrangham, R. W., & Boesch, C. 1999. Cultures in chimpanzees. *Nature*, 399, 682–685.

APPENDIX: CATEGORIZING BEHAVIORS

Theoretical considerations aside, the real test for a definition of tool use is how well it performs in categorizing observed animal behaviors. A definition might appear to be sufficient in the abstract, and yet produce entirely unintuitive results when applied. In this section, we compare the new definition to Beck's definition when applied to specific cases. A complete comparison would require a book-length treatment, but as a start, we can refer to smaller catalogs of behavior that have been developed. Whiten et al. (1999) list 65 behavior patterns that are part of chimpanzee material culture, and van Schaik et al. (2003) list 36 comparable behaviors for orangutan culture, though cases are not categorized with respect to tool use in either list. Beck (1980, pp. 5–6) lists 50 cases of behaviors categorized as tool use or tool-related behavior in the literature, with a discussion of how his definition applies (and sometimes disagrees with the judgments of the original researchers). Cases in the first two catalogs are interesting because they deal with a variety of behaviors that are associated with material culture, rather than specifically with tool use. The lists thus provide a good selection of potentially difficult boundary cases on which the categorizations of Beck's definition and the new definition of tool use can be contrasted. Even for cases in which the definitions agree, it can be interesting to see differences in how the categorizations are justified.

A comparison of definitions in this area inevitably involves judgment calls, based to some extent on intuition, interpretation, and analogies. Where there is ambiguity, we explain how we reach our conclusions.

Orangutan Behaviors

The catalog of behaviors related to orangutan material culture is divided into 24 likely cultural variants and 12 additional rare behaviors (van Schaik et al. 2003), a division that is irrelevant to our concerns but affects the numbering of cases. Among the behaviors in the catalog, some do not involve manipulation of external objects (cases 3, 11, 12, 24; rare case 1): sounds made with the help of the hands, scratching, feeding, contact between individuals. These are excluded by both definitions because they do not involve manipulation of external objects. A number of other behaviors (cases 1, 5–8, 13, 20–23; rare cases 3, 4, 6–8), related to nesting, feeding, and locomotion or change in location, are also excluded by both definitions. These involve interaction with objects, but they are not manipulated for external effects. Beck's definition excludes these behaviors specifically because they do not involve objects that are held, at least at the level of abstraction at which the behavior is described. The new definition excludes the behaviors because the orangutan does not exert significant control over the object described (nest, dead tree, twig, etc.), and because the object is itself the target of the orangutan's action, rather than a distinct object mediating the interaction between orangutan and target. For example, case 6 describes building a nest between two trees. Objects manipulated during the building activity may or may not be tools, but the overall behavior does not fall within the new definition.

Other cases are unambiguously tool use according to both definitions (cases 9, 10, and 14–19; rare cases 2, 5, 10, and 11). These involve such behaviors as wiping with leaves, scratching or swatting with a stick, using leaves as gloves, and using sticks for probing. These cases meet Beck's definition in that the tool user orients a held object (leaves or a stick) to alter the condition of the body (cases 9, 10, and 14; rare case 2) or termite nests (rare case 10), or the position of insects (cases 15 and 17), fruit or seeds (cases 16 and 18), or water (case 19; rare cases 5 and 11). These cases also meet the new definition, but for slightly different reasons. In each case, the orangutan exercises a high degree of control over the tool. Further, applying the tool results in a dynamic, mechanical interaction with the target, applying a

force for stimulation (cases 9 and 10), cleaning by friction (case 14, rare case 2), splitting (rare case 10), or altering position (cases 15–19; rare cases 5 and 11). Case 15, in which a leafy branch is used as a swatter prevents bees or wasps from stinging, is an interesting variation for the new definition: the relevant mechanical interaction applies at the level of air currents affecting the bees or wasps rather than the more usual interactions that are perceptible to the tool user. In some cases, the tool also mediates sensory stimuli: for example, in case 16 a leaf glove prevents a spiny fruit from painfully damaging the hand. In case 17, “tree-hole tool use,” one aspect of the behavior is probing with a tool, an example of mediated sensory interaction.

Under the new definition, four cases can be described as tool use to mediate influence interactions. Case 1 describes a “kiss-squeak” behavior in which orangutans use leaves pressed against the mouth to amplify sound; case 4 describes a visual display in which leaves are wiped over the face and dropped; rare case 9 describes branch dragging as a display; rare case 12 describes an orangutan hiding behind a detached branch. By Beck’s definition, these behaviors may also be considered tool use, with some assumptions (e.g., in rare case 12 that the detached branch is held by the orangutan), and with the caveats identified above in our discussion of the interpretation of conditions.

Chimpanzee Behaviors

Chimpanzee culture is more complex than orangutan culture, with more variety in the interaction with objects, but the analysis with respect to tool use is comparable. The majority of cases in the catalog of chimpanzee material culture (Whiten et al. 1999) are counted as tool use by both definitions (cases 4, 8–10, 11–15, 18–24, 29–45, 47–50, and 57), based on an analysis similar to that given above for the orangutan examples. These cases include behaviors such as the use of sticks as hammers and probes, and leaves as wipes and sponges. Other cases are unambiguously excluded by both definitions (cases 5, 16, 17, 25, 27, 28, 46, 52, 56, 58, 59, and 65). Case 26, the use of a stone to prop an anvil, would be counted as tool use 10 under Beck’s definition, but is excluded from the new definition because the object is not controlled during use and produces no dynamic interaction, as discussed above with respect to Matsuzawa’s tree-structure analysis.

Two other behaviors involve sensory feedback. Case 1 describes the use of a probe to examine a location; the probe is then sniffed. Case 51 involves the inspection of a wound by dabbing it with leaves, which are then examined (e.g. for traces of blood). These cases may meet Beck’s definition under a broad enough interpretation of the alteration of the condition of the user. They fall the new definition because of the mechanical interaction involved. The probe contacts or scrapes the location, and the leaf presses or wipes the wound. These cases also fall under the new definition as examples of sensory information that is mediated by an object.

In chimpanzees, we see further examples of objects used for communication (cases 2, 3, 6, 7, 53–55, and 60–64): for example, shaking, dragging, or slapping branches, bending saplings, and so forth. As before, some of these cases can be categorized as tool use by Beck’s definition (cases 2, 3, and 53–55), under the interpretation that the object manipulation results in a change in the information visible or audible to a hypothetical observer. A few of these behaviors are excluded by Beck because the object being manipulated is not detached (cases 6, 61, 63, and 64), for example shaking a branch or a bending a sapling. Depending on the manipulability of these objects, they may be considered tool use under the new definition, as mediating communication, but more detail would be required to make this determination. The remaining cases (7, 60, 62) deal with objects that are not manipulated (e.g. slapping a branch), and so are excluded by both definitions.

More General Animal Behaviors

Of Beck's 50 "boundary" cases (Beck 1980), the two definitions agree that 17 are tool use (cases 2, 5, 7, 8, 9, 11, 13, 14, 16–18, 24, 27, 29, 32, 34, and 42) and that 20 are not (cases 1, 3, 12, 15, 19, 20, 22, 23, 25, 30, 31, 33, 37, 39, 40, 43, 44, 46–48). Tool-using behaviors include instances of animals manipulating sticks, branches, stones, pebbles, and cactus spines. Some of these depend on the interpretation of substances such as water droplets as objects. Excluded behaviors involve interaction with objects that do not meet Beck's criteria (e.g. the object is attached to the environment), and in which there is either a lack of control or an absence of mechanical interaction such that the behavior fails to meet the new definition.

Two cases could be considered examples of tool use for communication and are also classified as tool use by Beck. Case 4 describes a gorilla tearing up and waving saplings to discourage intruders, and case 6 describes a macaque discouraging an aggressor of the same species by picking up and brandishing an infant. Both examples are covered above in the body of this article.

The two definitions clearly disagree in seven other cases that Beck describes as tool use. Cases 26 and 28 describe a chimpanzee reaching suspended food by stacking boxes or by propping and climbing a stick, both classified as tool use, though Beck expresses dissatisfaction with his justification for the former case, as discussed above. Cases 45, 49, and 50 involve an animal covering itself with an object: a chimpanzee using cloth and vegetation for warmth, a hermit crab inhabiting an abandoned shell, and a human wearing a helmet. The new definition excludes these behaviors because the interaction is not dynamic. (In human activity, these types of objects would more commonly be described as equipment rather than tools.) Consider an earlier case (classified as tool use) in which an orangutan uses leaves as gloves. This example is similar to the case of human wearing a helmet, but while the helmet provides passive protection in the event that something strikes the wearer's head, the gloves are used to handle a specific spiny fruit with which the orangutan is interacting directly. A helmet being used to butt another object or surface directly *would* satisfy the new definition as tool use, both via the mechanical interaction and the mediation of sensory input.

Case 38 describes "a deer accumulating mud on its antlers to attract a mate." This case is categorized as tool use by Beck, though the case as described only ambiguously matches the criteria of his definition. It requires that mud be treated as an object, that mud on the antlers be considered an efficient alteration of the condition of the deer, and that the antlers be treated as carrying and orienting the mud. This behavior does not meet the new definition of tool use: the mud is not controlled in its use, even if it is treated as a discrete object. Case 41, a heron scattering bits of biscuits on the water to attract fish, has been discussed above.

Finally, the new definition classifies as tool use some behaviors excluded by Beck. Case 21, a bird pulling up a string to obtain food tied to the end has been previously discussed. Cases 10, 35, and 36 are examples of humans using complex machinery, and such technology is likely to lead to many ambiguous cases. Cases 35 and 36 refer to a horse-drawn and a tractor-drawn plow respectively; to the extent that a human operator is directly responsible for guiding the plow, we can consider this to be tool use under the new definition, even though the human does not physically propel the plow. Case 10 describes a human hunter using a rifle to kill an antelope. Beck (reluctantly) does not classify this as tool use because the human is not responsible for the effective orientation of the "object" (presumably the bullet). However, if we consider the rifle as a means not to kill the antelope, but rather to simply accelerate the bullet, we can reasonably consider this to be case of tool use under the new definition.