6 Understanding differences in the way human and non-human primates represent tools: The role of teleological-intentional information

April M. Ruiz
Yale University, Department of Psychology

Laurie R. Santos
Yale University, Department of Psychology

Introduction: redefining man or redefining tools?

On a morning in 1960, Jane Goodall made an observation that would forever change the way scientists think of our own species' place in the animal kingdom: she observed a non-human animal fashioning and using a tool. There, for the first time, Goodall witnessed the famous Gombe chimpanzee David Greybeard fishing for termites. She watched as, over and over, he grabbed a twig, stripped off its leaves, placed it inside a termite mound, and then retracted it to lick off a pile of termites. Even on that morning, Goodall recognized the significance of her observation (Goodall, 1986). At the time, scientists had assumed that humans were the only species capable of a cognitive feat like Greybeard's termite fishing. Indeed, sophisticated tool use had long been heralded as one of the key differences between humans and other animals. With a single observation, Goodall had challenged this understanding of non-human cognition. She excitedly detailed her findings in a telegram to her mentor, the anthropologist Louis Leakey, who replied with his now famous rejoinder: "Now we must redefine 'man,' redefine 'tool,' or accept chimpanzees as humans."

In the five decades that have followed Goodall's original observation, scientists are still struggling with the particulars of Leakey's interpretational challenge. On the one hand, researchers have learned much more about the impressive nature of non-human tool use, thereby redefining what it means to be a tool-using creature. We now know, of course, that humans and chimpanzees are not alone in their use and design of tools. Since Goodall's original observations, scientists have documented cases of tool use in nearly every taxa of the animal kingdom (see reviews in Beck, 1980; Hauser, 2000). We've observed capuchins using hammers (Ottoni & Izar, 2008; Chapter 10), orangutans using spears (van Schaik *et al.*, 2003), cephalopods using costumes (Finn *et al.*, 2009) and crows making fishing hooks (Weir *et al.*, 2002; see also Chapter 5). Indeed, non-human tool use is now known to be both

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varied – involving a variety of different kinds and combinations of tools – and flexible – with many species employing tools to solve an array of different kinds of problems.

On the other hand, despite learning more about the impressive nature of non-human tool use, there is no denying that humans are special when it comes to the world of tools. Chimpanzees have termite probes and stone hammers, but humans have microscopes and bulldozers, not to mention airplanes, cellphones, microwaves and supercomputers. A quick look at any human living in the modern world reveals that human tool use can be far more varied, complex and specialized than that of any non-human studied to date. More so than any other creature, humans have developed an environment brimming with tools. Unlike non-human animals that tend to use tools for only a small subset of their daily tasks, humans use tools to alter nearly every facet of our daily lives. In doing so, our species has developed a material culture that is undoubtedly unique in both its complexity and its scope.

The puzzle for scientists, then, is the question of *why* human tool use is so different than that of other animals. Clearly, many non-human animals have the cognitive skills to make and use an impressive array of tools. Why, then, don't these species also experience a human-like explosion of tool use and material culture? What differences at the cognitive level account for the wide gap between human and non-human tool use? More specifically, what cognitive capacities are required not just for being a tool user, but also for being a *human-like* tool user?

In this chapter we present one hypothesis for the unique nature of human tool use. In contrast to some previous accounts (e.g., Povinelli, 2000), we argue that the human species' superiority does not emerge because of a human-unique prowess in physical or causal cognition. Indeed, we review recent work suggesting that many species possess a human-like degree of cognitive sophistication when it comes to reasoning about the physical and functional properties of a good tool. Instead, we argue that although humans and other primates share a sophisticated ability to recognize the functionally relevant aspects of tools, they differ greatly in how they reason about the *socially relevant* aspects of tool use and design (see Hernik & Csibra, 2009 for a similar argument). We review recent developmental data on intentional reasoning in humans and the consequences that this emerging understanding has for our understanding of tools. We then review recent social cognition work in non-human primates[1] to suggest that human and non-human primates may differ in their use of intentional information when representing tools. Specifically, we will argue that primates tend to weight physical information more than intentional information when representing the tools around them. We then discuss how this socio-cognitive difference could have led to the wide gap between the kinds of tool use we see in humans versus other species.

What non-human primates know about the physics of tools

As any good human carpenter can attest, one important aspect of being a good tool user is knowing which tool is needed for a specific job. At a physical level, this usually means

[1] Throughout our review of animal tool use, we've chosen to focus only on tool use in the primate order. That said, we believe our analysis of what makes tool use unique will apply equally to non-human animals in other taxa (for a review of work in this area, see Hunt *et al.*'s and Tebbich's chapters in this volume).

recognizing how a tool's physical properties will affect its ability to bring about the desired goal. If your goal is to drive a nail into a board, then you'll need a tool with certain kinds of physical properties: in this case, one with a hard surface rather than a soft one. In contrast, if you need to clean up a spill, then you'll need a tool made out of an absorbent material rather than one that's waterproof. The capacity to recognize which physical properties are pertinent to a tool's functionality has long been thought to be one of the important cognitive components of successful tool use (e.g., Tomasello & Call, 1997; Povinelli, 2000; Santos *et al.*, 2003; Hauser & Santos, 2007; Visalberghi *et al.* 2009)

Given limitations in the scope of non-human primate tool use relative to that of humans, one might initially assume that primates lack an awareness of the functional properties of objects. Indeed, only a decade ago many primate researchers shared this assumption, arguing that primates probably lacked the ability to recognize which physical affordances made an object a good tool (e.g., Tomasello & Call, 1997; Povinelli, 2000). More recent experimental work, however, has demonstrated that several primate species seem to recognize the functionally relevant aspects of potential tools, particularly when these features are readily observable (see reviews in Hauser & Santos, 2007; Penn & Povinelli, 2007). In a typical study, primates are presented with an out-of-reach food reward and given a choice of possible tools with which to obtain the food (capuchins: Fujita *et al.*, 2003; Cummins-Sebree & Fragaszy, 2005; chimpanzees: Furlong *et al.*, 2008; macaques: Ueno & Fujita, 1998; Maravita & Iriki, 2004; lemurs: Santos *et al.* 2005a; marmosets: Spaulding & Hauser 2005; tamarins: Hauser 1997; Hauser *et al.* 2002a; Hauser *et al.* 2002b; Santos *et al.* 2005b; Spaulding & Hauser 2005; vervet monkeys: Santos *et al.*, 2006b). Across a number of different kinds of manipulations, primates generally perform well on these tasks, reliably differentiating between tools that can and cannot be used to obtain the food. Furlong *et al.* (2008), for example, presented chimpanzees with a situation in which different kinds of tools could be used to take in an out-of-reach piece of food. They observed that chimpanzees spontaneously attend to the feature of rigidity when choosing a possible pulling tool, selectively choosing rakes with rigid tops over ones with flimsy tops (for similar results on an analogous task in other species, see: cotton-top tamarins: Santos *et al.*, 2006b; vervet monkeys: Santos *et al.*, 2006b). Primates also seem to recognize that some aspects of a tool's shape matter for its function; ring-tailed lemurs, for example, reliably choose tools with hook-like shapes at the top over tools with shapes that are less effective at hooking a piece of food (see Figure 6.1). In this way, lemurs seem to recognize how different kinds of shapes can affect a tool's functionality (for similar results on an analogous task in other species, see capuchins: Cummins-Sebree & Fragaszy, 2005; cotton-top tamarins: Hauser, 1997; Hauser *et al.*, 2002a; Hauser *et al.*, 2002b; Santos *et al.*, 2005b; Spaulding & Hauser, 2005; great apes: Marin-Manrique & Call, 2010). Finally, primates are successful at ignoring salient perceptual changes that don't affect a tool's function; having been trained to use a pulling tool of one color, vervet monkeys reliably ignore salient color changes even though they avoid tools of a new shape and rigidity (Santos *et al.*, 2006b; for similar results, see: capuchins: Cummins-Sebree & Fragaszy, 2005; cotton-top tamarins: Hauser, 1997; marmosets, lemurs: Santos *et al.*, 2005a).

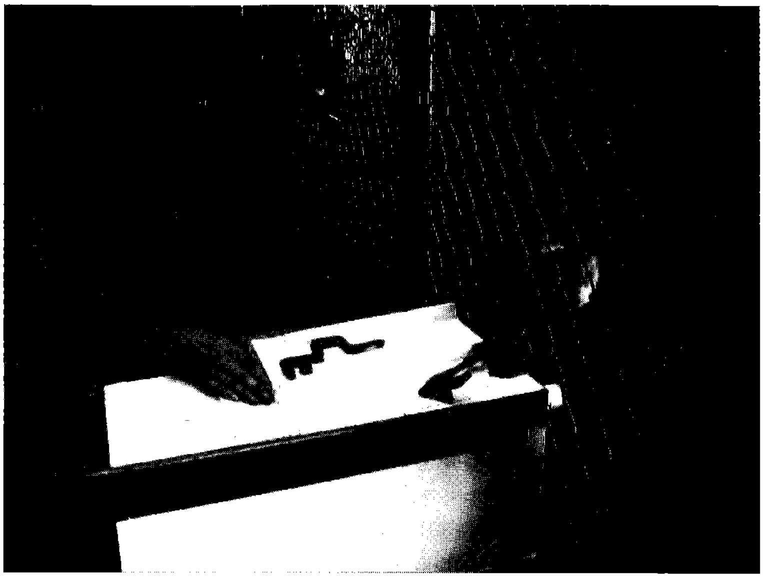

Figure 6.1 The lemur tool task used in Santos *et al.* (2005a). Lemurs were given a choice of tools whose shape varied. Subjects reliably chose tools with shapes that were functionally relevant for the pulling task.

This attention to the functional features of tools has also been observed in recent experimental work with primates living outside of captivity (see review in Chapter 10). For example, Santos *et al.* (2003) examined whether free-ranging macaques understood the functional features of a tool by using an expectancy violation looking-time study. In this study, macaques were allowed to watch as a human experimenter used a tool to push a grape along a stage. After being familiarized to one kind of tool, monkeys saw several test trials in which the experimenter used a novel tool, one that had changed either in a functionally relevant feature (e.g., shape) or a functionally irrelevant feature (e.g., color). Santos and colleagues found that monkeys looked at the display significantly longer when a newly shaped tool appeared to push the grape, but showed no increase in looking when a newly colored tool performed the same action. In this way, macaques appear to recognize that shape properties are more relevant than color for a tool's function, even in cases when they themselves don't have an opportunity to directly act on the tools. In another set of studies, Visalberghi *et al.* (2009) presented stone-hammer-using wild-bearded capuchin monkeys with novel stone-hammer tools that varied in size and weight. They found that monkeys reliably attended to these features, selectively choosing hammers that were large and heavy enough to crack nuts. Monkeys attended to the correct dimensions even when these features were pitted against each other, selectively choosing a heavy stone that looked small over a light stone that looked larger. Taken together, this body of work suggests that many primates can use a potential tool's observable properties to determine whether a tool will be effective for a certain kind of function. As such, primates' limited tool use cannot be solely the result of a lack of functional understanding at the level of physical affordances.

Although primates do well on tool tasks when dealing with perceptually obvious physical affordances, there is some evidence that primates perform more poorly when a tool's causal properties are less perceptually obvious. For example, primates fail tool-choice tasks that require them to take into account causal forces such as gravity and support. Cotton-top tamarins and vervet monkeys, for example, perform at chance on a tool-choice task that requires them to attend to the substrate on which a tool acts, ignoring small traps that could impede a tool's trajectory (Santos *et al.*, 2006b). Even more competent tool users, such as chimpanzees and capuchins, do poorly on tool tasks that involve unobservable forces like gravity and support (Visalberghi & Trinca, 1989; Povinelli, 2000; Girndt *et al.*, 2008; Seed *et al.*, 2009, but see Hanus & Call, 2008 and Visalberghi *et al.* 2009 for some examples of primates successfully representing unobservable forces). In this way, non-human primates' functional understanding of the physics of tool use appears to be limited to cases in which the physical affordances are perceptually obvious.

While non-human primates' difficulties in reasoning about the unobservable properties of tools may seem like an obvious spot in which their cognitive limitations might hinder tool use, it's also important to note that limitations in non-obvious causal understanding are not only the case for non-human species. Indeed, a growing body of work suggests that even *human* primates possess an unusually limited understanding of the unobserved causal forces that affect a complex tool's function. Although humans in principle have the potential to understand unobservable causal forces as complex as quantum mechanics, work by Keil and colleagues has documented that most people actually know relatively little about the causal properties of even simple tools when probed directly (see review in Keil, 2006). For example, Rozenblit and Keil (2002) found that adult humans can't report how simple mechanical tools – such as zippers, can openers and cylinder locks – actually work. Although participants obviously can be made to understand how these objects work when explanations are provided, in the absence of specific training most people are unable to report how these very simple tools actually function. In an even more surprising failure, Lawson (2006) found that people from a variety of backgrounds (including bike experts) failed to understand even the simplest aspects of how a bicycle works. In practice, then, people also appear to have very limited causal knowledge of the unobservable features of the tools, even when they use such tools every day. Given that humans also appear to have a rather limited physical understanding of the simple tools, how does our species come to successfully deal with and effectively use the many causally complex tools that make up the modern world? If humans don't fully grasp the physics of zippers and screwdrivers, how do they come to successfully use complex tools like microwaves and computers?

Human tool use in a social context

The answer may be obvious to anyone who's ever watched a friend play with his new iPhone, seen a child explain how to use the new videogame controller or observed a television chef use a new kitchen gadget. As humans, much of our understanding of how to use novel tools comes from watching other individuals. Human tool use naturally occurs in a social context; from the time we grow up, we are surrounded by informed conspecifics using complex tools with a specific goal in mind. In this way, we often use social information to go beyond a tool's physical properties in order to figure out how to use a variety of complex tools, even ones whose causal properties we don't fully comprehend at a physical level.

Recent work in developmental psychology has shown that human children come to develop this sort of socially mediated understanding of tools even within the first few years of life. One of the earliest emerging aspects of this understanding is the tendency to think about tools *teleologically* – in terms of *what an intentional agent designed them for* (see Kelemen, 1999a; German & Johnson, 2002; Kelemen & Carey, 2007; Hernik & Csibra, 2009). This teleological stance – representing tools in terms of how they are typically used by others and what kinds of goal-directed actions they were designed to perform – seems to be incredibly important in children's early construal of tools, sometimes even trumping information about a tool's physical properties. By kindergarten, children think that a tool "is" whatever it was designed for, not what it could potentially be used for (Kelemen, 1999a). In one example, Kelemen (1999b) introduced children to a novel tool that was invented to stretch clothes that got shrunk in the wash, but also could be used by people to help stretch their backs. Even though this object was physically able to do both tasks, children reliably reported that this tool *was* a "clothes stretcher," namely the function for which the object was originally invented. Kelemen and colleagues have observed similar teleological biases in even young children. Casler and Kelemen (2007) introduced 24-month-old children to a novel tool performing a particular function (e.g., a "bell-ringer") and children were then allowed to generalize this tool's function to other tasks for which it was equally physically suited (e.g., "pasta crusher"). Even after a lengthy delay, they found that two-year-old children only used the object for its original function, using it to ring bells but not to crush pasta. These results suggest that by two years of age children think of tools not in terms of their physical affordances, but in terms of the goal for which other agents typically use the tools.

In addition to thinking about tools in terms of what they are used for, children also pay special attention to the intentions behind an agent's tool use. Children, for example, seem to care a lot about the intent of a tool's designer and the goal for which this individual intentionally created and used the tool (see Bloom, 1996). Kelemen (1996b), for example, found that children discredit objects that are accidentally used in a certain way, suggesting that an agent's intent has a big impact on how children think a tool should be employed. Bloom (1996) has argued that humans naturally construe tools in terms of their intended history, weighing intentional aspects of a tool's design even more heavily than a tool's physical properties when deciding what a tool is and how it should be used. Bloom points out that we readily label a tool based on what it was designed to do, even in cases where that object no longer has the physical properties needed to fulfill its original goal. In line with this claim, Kemler Nelson *et al.* (2004) showed children common household tools that were broken (e.g., a fork with its tines missing, a safety pin with its receiving end bent) and were thus no longer able to physically perform the actions they were designed to perform. In spite of this, children still labeled these objects as "forks" and "safety pins." In this way, children appear to categorize an object as a particular kind of thing based on its intentional history, not on its physical properties or affordances.

In all of the above cases, children's combined teleological-intentional stance toward tools allows them to go beyond physical affordances alone when representing how a tool works and what it can be used for. These socially mediated aspects of our human tool representations allow for several of the more impressive aspects of human tool use (see review in Hernik & Csibra, 2009). First, our teleological-intentional stance allows us to represent and use any tools demonstrated by a social agent, even when that tool's physical affordances are causally opaque. Humans are, of course, renowned for using artifacts whose physical affordances are both hidden and relatively complex (e.g., a computer with many complex inside parts), a skill that likely results from our ability to glean functional information from others' object-directed actions even in the absence of physically relevant information (see discussion in Hernik & Csibra, 2009).

Nevertheless, our teleological-intentional stance is not without its problems. Humans are sometimes so susceptible to social information about what a tool is for that such information prevents us from making use of a tool's obvious other physical affordances (see review in Hernik & Csibra, 2009). For example, psychologists have long known that adult humans are susceptible to *functional fixedness*, a bias in which we can only view a tool as capable of performing the function for which it was designed. In an original version of this task (Duncker, 1945), adult participants failed to realize that the physical properties of a tool designed to be used as a container (e.g., a tack box) also rendered it capable of being used as a support. Recently, German and colleagues have demonstrated that functional fixedness is a widespread phenomenon; it has been observed in children as young as seven (German & Defeyter, 2000; Defeyter & German, 2003), and also in populations that lack technologically rich environments, such as the Shuar of Ecuadorian Amazonia (German & Barrett, 2005). Humans' early reliance on social information when learning about artifacts can also lead children into a bias known as *overimitation*, in which children follow an adult's way of operating a tool so closely that they incorporate actions that they know are causally irrelevant (Horner & Whiten, 2005; Lyons *et al.*, 2007; McGuigan *et al.*, 2007; Kenward *et al.*, 2010; Nielsen & Tomaselli, 2010). In one overimitation study, Lyons *et al.* (2007) presented children with a novel artifact – a puzzle box that could be opened to reveal a toy. Children were then allowed to watch as an adult demonstrator opened the box. The demonstrator performed two kinds of actions when opening the puzzle box: a causally relevant action, that is, one that was physically necessary for opening the box (e.g., removing a door that blocked the toy); and a causally irrelevant action (e.g., tapping on the top of the box) that even the children knew was irrelevant to actually retrieving the toy. Lyons and colleagues found that children were much more likely to perform the irrelevant actions after watching the adult demonstrator perform them. Merely watching an adult intentionally act on an object therefore appears to change the way children will interact with that object (see also Horner & Whiten, 2005; McGuigan *et al.*, 2007). Indeed, Lyons and colleagues observed that children continued to make this error even when specifically trained to recognize "silly" unnecessary actions and told to not copy these, suggesting that this phenomenon may be more automatic than previously suspected. Indeed, children who grow up in technologically sparse cultures show similar levels of overimitation as children in Western cultures (Nielsen & Tomaselli, 2010).

Lyons and colleagues have interpreted these overimitation results as evidence that another agent's social actions can drastically change the way children represent the causal aspects of how a tool works. Specifically, they have argued that watching someone use a tool intentionally can alter the way a child thinks that tool works physically, especially in cases in which adults act on the tool in inefficient ways. As such, overimitation suggests that children may regularly override their knowledge of an object's functional properties when faced with conflicting social information. In this way, social information seems to deeply affect the way children come to learn about how a tool works.

Is there a social context to non-human primate tool use?

The work reviewed above suggests that social information has a critical impact on the way humans represent and learn to use tools. Do similar factors affect non-human primates' understanding of tools? Put differently, do primates also take a teleological-intentional stance when representing tools? Before launching into whether non-human primates bring an intentional understanding to the tools they use, it's worth noting that primates *do* possess the socio-cognitive capacities needed for a teleological-intentional construal. More specifically, there is a growing body of work in the domain of primate theory of mind suggesting that non-human primates can in fact represent other individuals' actions in terms of their underlying intentions. Chimpanzees, for example, have been shown to selectively imitate a human experimenter's intended actions rather than the accidental actions they actually demonstrate (see Myowa-Yamakoshi & Matsuzawa, 2000; Tomasello & Carpenter, 2005; Buttelmann *et al.*, 2007; see Meltzoff, 1995 for a version of this task in human infants). There is also evidence that chimpanzees (Call *et al.*, 2004) and capuchin monkeys (Phillips *et al.*, 2009) can distinguish between a human who is unwilling to share food and one who intends to share food but is unable to do so (see Behne *et al.*, 2005 for a similar study in human infants). Both chimpanzees and capuchins leave a testing area sooner when dealing with an unwilling experimenter than when dealing with an experimenter who intends to share but has become clumsy. These and other results (see review in Tomasello *et al.*, 2005) suggest that several non-human primate species can detect and use information about an agent's goals and intentions when reasoning about others' actions. These recent theory of mind studies suggest that non-human primates do possess the intentional representations needed for the kind of social construal humans take when representing tools.

The question, then, is whether non-human primates actually *use* the intentional information they represent in theory of mind tasks when learning about how a novel tool works. Unfortunately, only a limited body of work has addressed this issue directly. The work performed to date, however, suggests that primates may be limited in their use of teleological-intentional information. In an early study, Nagell *et al.* (1993) compared children's and chimpanzees' performance on a tool task in which a demonstrator modeled how to use a rake-shaped tool to obtain out-of-reach rewards. In one condition, the participants saw the demonstrator model an effective strategy: placing the rake with the tines facing up, such that the flat edge was able to rake in more rewards. In the other condition, participants saw the demonstrator use a less effective strategy: positioning the rake with the tines down, such that rewards were able to slip through. Children learned to use the tool differently depending on which demonstration they saw, performing worse (i.e., using the tool in such a way that they retrieved fewer rewards) when they saw the demonstrator use the less effective strategy. Chimpanzees, in contrast, were unaffected by the demonstrator's strategy; although they benefited from seeing a model perform the action, they performed equally well on the task no matter which of the two modeled strategies they saw. This early result established that chimpanzees are less affected by the social aspects of tool use they see than human children are.

In a more recent study, Horner and Whiten (2005) directly examined whether chimpanzees were as susceptible as human children to intentionally perform irrelevant actions. They gave chimpanzees and children puzzle boxes like those used by Lyons *et al.* (2007). The subjects were then allowed to watch as an adult human demonstrator illustrated how to open the box using both causally relevant and irrelevant actions. In one condition, the box was opaque, making it difficult for children and chimpanzees to understand which actions were causally relevant and which were irrelevant. Horner and Whiten found that both children and chimpanzees copied the demonstrator's actions in this condition. When chimpanzees were not given any information about the box's physical affordances, they could socially learn from the demonstrator's actions just as well as the human children did. Horner and Whiten also presented both subject groups with a second condition in which the puzzle box was transparent rather than opaque; as such, the physical affordances of the box were made more perceptually obvious, clearly showing which actions were causally relevant and which were irrelevant. Here, Horner and Whiten observed a striking difference in the performance of the two subject groups. As in the study by Lyons *et al.* (2007), children overimitated in the transparent condition, ignoring what they knew to be true about the box's physical affordances after watching an adult intentionally act on the box. Chimpanzees, in contrast, completely ignored the experimenter's irrelevant actions in the transparent condition; when performing the action themselves, chimpanzees eliminated obviously unnecessary steps, acting on the box in the most efficient way (Horner & Whiten, 2005).

Interpreting non-human primates' inability to use teleological-intentional information to represent tools

Although non-human primates represent intentions in a number of different theory of mind tasks, the studies performed to date on primate overimitation demonstrate that non-human primates may not take the kind of teleological-intentional stance that humans do when representing tools. Although other primates can learn socially how to use a tool, they are more swayed by physical information than by a model's intentional actions. While humans represent tools as objects that are *for* the purpose of achieving a specific intention or goal, non-human primates appear to focus more on the physical properties of tools; other primates tend to ignore information about why a tool was designed and how it has historically been used by others. It is possible, then, that this is one of the differences that makes human tool use unique – humans employ their intentional understanding to make sense of the tools around them, but non-human primates do not (or perhaps more accurately, cannot) employ the same understanding when representing tools (see Hernik & Csibra, 2009 for a similar conclusion).

The difficult question now facing researchers is *why* non-human primates don't use a teleological-intentional construal when thinking about tools. Hernik and Csibra (2009) offer an interesting analysis of this question, providing one possible way to interpret the unique nature of humans' teleological-intentional stance. They argue that non-human primates may fail to employ a teleological-intentional stance in part because other primates cannot attend to goals and intentions in the same way as humans; in their view, other primates "do not search for goals" (p. 36). Their review hints that non-human primates might lack more general representational structures for representing goal-directed actions, and thus do not have systems to make sense of goal-directed actions that involve tools. If non-human primates did lack intentional understanding in the way Hernik and Csibra suggest, then they would not be able to bring social information to bear when analyzing how tools work.

Although we agree that non-human primates may not find goals as salient as our own species does, we disagree with Hernik and Csibra's implication that non-human primates *cannot* attend to goals. As we reviewed above, there is strong evidence from studies of theory of mind that primates *can* attend to intentional information when they're not reasoning about others' tool use – non-human primates distinguish between accidents and intentions (Tomasello & Carpenter, 2005), seek out other agents with good intentions (Call *et al.*, 2004; Phillips *et al.*, 2009) and sometimes imitate others' intended actions (Buttelmann *et al.*, 2007). Moreover, chimpanzees do sometimes use information about a person's intentions when representing how a tool works (Horner & Whiten, 2005); the difference, though, is that chimpanzees *only* seem to employ intentional information when the tool in question lacks any obvious physical affordances that might provide clues as to how that particular tool works.

Faced with this pattern of results, we favor a slightly different interpretation than Hernik and Csibra (2009). We argue that non-human primates can attend to intentional information, even when representing tools, but often choose not to weight this information very heavily. Consider, for example, chimpanzees' performance in Horner and Whiten (2005). When the puzzle box tool had no obvious physical affordances (the opaque condition), chimpanzees attended to a demonstrator's intentionally directed actions on the box and copied these actions well in order to obtain the food. In contrast, when the puzzle box had obvious physical affordances, chimpanzees ignored the demonstrator's intended actions. Unlike children, chimpanzees appear to weight physical information more heavily than others' intentional cues when trying to learn how a new tool works. In this way, chimpanzees may be able to use intentional cues when representing tools, but fail to do so in cases where more obvious physical cues are available.

Our idea that chimpanzees and humans differ in their weighting of teleological-intentional cues makes a few relevant predictions when you consider how such a differential weighting might play out in the actual way that humans and non-human primates tend to learn about new tools. Consider perhaps the most prolific non-human tool user, the chimpanzee. Even though chimpanzees use a varied set of tools, they still grow up in a world where nearly all tools available have perceptually obvious functional properties. In a chimpanzee's natural habitat, the most complex tools (e.g., Chapter 8) involve very simple, observable physical affordances: large, heavy objects like hammers; skinny, probing objects like termite-fishing poles; etc. Any situation involving the use of these tools would be a case in which the perceptual aspects of the problem were obvious and, as such, chimpanzees would not be expected to attend to intentional information when watching others using tools. If chimpanzees weight physical information over social information, it would likely mean that they rarely, if ever, resort to thinking of their own real-world tools in terms of intentional information; all tool problems they face would be easily understood using physics alone. In this way, a slightly differential weighting of physical and social information of the kind we've argued for here could lead to large differences in the way chimpanzees see the tools around them. The same would be true for other tool-using non-human primates, who also lack tools with perceptually opaque features in their natural environment.

Our idea that non-human primates selectively weight physical over social information makes a few testable predictions about non-human primates' use of the teleological-intentional stance when watching others' tool use. First, non-human primates should not show the kinds of errors that humans show when given problem-solving tasks involving novel tools. Put differently, non-human primates should be *less* functionally fixed than humans (e.g., Duncker, 1945) – they should be just as successful on an insight problem-solving task when presented with a tool with a known function as when presented with a completely novel tool. This prediction is, in some sense, counter-intuitive. Recall that functional fixedness hinders human tool use, making human participants less good at coming up with solutions to novel tool problems. Our analysis, then, would predict that non-human primates could, in some situations, outperform adult humans on tool tasks, particularly in cases when successful tool use requires inhibiting teleological-intentional information. Primate researchers could therefore profit from developing this kind of functional-fixedness test for non-human primates, perhaps borrowing designs used in developmental studies (e.g., German & Defeyter, 2000).

Another prediction that follows from our analysis concerns ways to teach non-human primates to become better tool users. Our view is that non-human primates *can* attend to teleological-functional properties, but tend not to find this information salient. One possibility that follows from this view is that one might be able to induce non-human primates to use tools with more causally opaque affordances, thereby making intentional information more salient (see, for example, Hanus *et al.*, 2011). Theory of mind studies have found ways of making non-human primates attend more directly to intentional information by making goal-directed gestures more obvious or contextually salient (e.g., setting experiments in a competitive context; see Hare, 2001; Lyons and Santos, 2006; Santos *et al.*, 2006a). Future research may be able to use similar manipulations in tool-use studies in order to force non-human primates to attend to intentional information. We would predict that such manipulations could naturally nudge non-human primates toward more complex tool-use understanding.

In conclusion, then, we have argued that a small difference in attention toward different kinds of information may have led to a cascade of qualitative differences in the kind of tool use of which a species is capable. Humans' sophisticated modern tool use could be predicated on our (perhaps unique) tendency to naturally track social over physical information when watching goal-directed actions on objects. In contrast, we've argued that non-human primates tend to weight physical over social information when watching agents act on objects. This subtle difference in non-human primates' weighting of information may limit the kinds of things they can learn about tools that lack obvious perceptual affordances. In this way, a slight difference in a species' attention to physical versus intentional information may have tipped the balance for our own species, allowing us to ratchet up our material culture in ways no other species has experienced. In this way we've tried to offer an answer to Leakey's challenge. Rather than redefining "man" or "tools," we may need to take a more subtle approach – recognizing that how a species naturally attends to different kinds of information can have large cascading effects on the kinds of material culture they can naturally develop.

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