

Comparing the imitative skills of children and nonhuman apes

Malinda Carpenter

Josep Call

Max Planck Institute for Evolutionary Anthropology, Leipzig, Germany

In press (since 2007), *Revue de Primatologie*.

Running head: Imitation in children and apes

Please send correspondence to:

Malinda Carpenter or Josep Call

Max Planck Institute for Evolutionary Anthropology

Deutscher Platz 6

D-04103, Leipzig, Germany

Email: carpenter@eva.mpg.de, call@eva.mpg.de

Key words: social learning, apes, enculturation, imitation, emulation, shared intentionality

Abstract

We propose a framework which breaks down the mechanisms of social learning into their four constituent elements: actions, results, goals, and context. We review what is known about the use of each of these elements in children's and apes' social learning, with special attention to possible differences among apes with different rearing histories. We conclude that, by 12 months of age, human infants use each of the four elements when interpreting and selectively copying others' behavior. Apes, on the other hand, appear to focus solely on the results of demonstrations (although there is some suggestive evidence that enculturated apes may copy actions and goals more than other apes). Finally, we show how these (and other related) findings can be explained by uniquely human skills and motivations for shared intentionality.

Comparing the imitative skills of children and nonhuman apes

Years ago, one of us was at the Barcelona Zoo filming the gorillas for a school project. A classmate remarked with excitement that the gorilla we were filming was imitating her. The classmate proceeded to show us how her head-bobbing motions were followed by similar actions by the gorilla. The scene looked truly compelling. However, upon reviewing the tape we discovered that the initiator of the head-bobbing actions had been the gorilla, not our classmate. So in reality, it was our classmate who was aping the ape rather than the other way around.

This story contains two important lessons. First, humans are terrific imitators, not only of their own species but also of other species. Second, although apes are also widely believed to be terrific imitators, this example and a wealth of experimental evidence show that this is an inaccurate representation of reality. But at the same time, the story is also more complicated than this: in social learning situations, humans do not always copy others' behavior, and apes do copy some aspects of demonstrations. In this article, first, we present a framework for thinking about social learning which specifies the different elements observers can pick up and copy from demonstrations. Then we review evidence from human children and apes to see which of these elements each can use. We report results for apes with different rearing histories separately because there have been claims that a special group of apes, 'enculturated' apes who have been raised by humans, may copy different aspects of demonstrations than apes reared by conspecifics (e.g., Bering, 2004; Call & Tomasello, 1996; Hayes, 1951; Tomasello & Call, 2004). Finally, we discuss how differences between humans and apes may have come about.

What is imitation?

Imitation is a useful and useless term at the same time. On the one hand, the term imitation is useful because people can quickly relate to it: it is about social interaction and reproducing someone's behavior. A single word instantly carries a lot of meaning. On the other hand, imitation is a useless term because the meaning that it brings to some people is different from that which it brings to others. For instance, imitation is used in the literature to denote copying actions, learning novel actions, and in some cases copying not just actions but results and even intentions as well.

Various authors have attempted to classify these different meanings by introducing other terms (e.g., Tomasello, 1996; Want & Harris, 2002; Whiten & Ham, 1992; Zentall, 1996). For example, *emulation* refers to the reproduction of the results of a demonstration, not the behavior that produces those results, whereas *goal emulation* refers to the reproduction of what the demonstrator was trying to accomplish, not what she actually accomplished or the behavior that she used. *Mimicry* is typically used to refer to the reproduction of behavior with no understanding of the demonstrator's intention, whereas *imitative learning* refers to the reproduction of both the behavior and the intention of the demonstrator. However, some authors use the term *imitative learning* without reference to the intentions of the demonstrator, and some use *mimicry* to denote 'copying' of even non-behavioral, physical aspects such as coloration in snakes or insects.

Although the use of this more specific terminology is leading to more accurate characterizations of how various organisms learn from each other, we think that too much emphasis is placed on the mechanisms rather than on their constituent components, the types of information that are copied. In our view, this is analogous to building a chemistry based on compounds (i.e., molecules) rather than one based on elements (i.e., atoms), the

constituent components of those compounds. In social learning, the mechanisms used by various authors (e.g., emulation, mimicry) are the compounds (Carpenter & Call, 2002).

We have proposed a more systematic framework for thinking about social learning which breaks down the mechanisms of social learning into their three constituent elements (see Call, 1999; Call & Carpenter, 2002; Carpenter & Call, 2002). We noted that observers can potentially obtain three sources of information from a demonstrator: actions, results, and goals. Combinations of these elements easily map onto the classic terms: action only = mimicry; result only = emulation; goal only = goal emulation, and action + result + goal = imitative learning. However, our element-based approach has several advantages over the compound-based approach. First, different combinations of these three elements produce not only the ‘classic’ mechanisms but also other mechanisms that have not yet been so well documented (e.g., Heyes & Ray’s, 2002, “outcome-sensitive imitation” is action + result, and Want & Harris’s, 2002, “blind imitation” is action + goal and “insightful imitation” is action + goal + result).

The simplicity of our three-element system, however, does not mean that each of the three types of information, like atoms, constitutes an indivisible unit. We know that atoms can be split into subatomic particles, which in turn can be split into even more elementary particles. Similarly, there are different levels within each of our three elements. *Goals* can include goals and intentions, and even different types of intentions such as intention in action and prior intention (see Searle, 1983; Tomasello, Carpenter, Call, Behne, & Moll, 2005). *Actions* can include the general movements, the particular style (Hobson & Lee, 1999), and other details all the way down to which hand was used and the exact position of the fingers, muscles, etc. Within *results*, one can reproduce the end state with or without learning about new affordances and causal relations (Want & Harris, 2002).

Call and Carpenter (2002, see also Carpenter & Call, 2002) also pointed out that observers can change their focus of attention from one element to another across different tasks and even during repeated trials within the same task, and that this interacts with their prior knowledge and ongoing practice with the task. Another advantage of this approach is thus that instead of simply characterizing species as "imitators" or "emulators" we can move beyond these rather blunt characterizations. For example, although many studies show that human infants are good imitators (i.e., they copy others' actions for the same goal), several recent studies (see below) suggest that infants also engage in goal emulation. What these two social learning mechanisms have in common is goals, not actions. We thus think that copying actions is important for infants but that it is lower in the hierarchy than copying goals (see Bekkering, Wohlschläger, & Gattis, 2000, for more discussion). If we simply characterized young children as "imitators" we would miss out on this important point.

Recently, we revised our original framework and added 'reality' or context as a fourth component (Call & Carpenter, 2003). Bekkering and colleagues (see below) have demonstrated the importance of the context for the way in which human children, at least, interpret others' actions and decide what to copy. The effects of context can influence each of the other sources of information. Context can affect actions, for example, when the demonstrator uses one stick to fish for termites and the observer uses a different stick with a different degree of flexibility or number of branches. In this case even observers who attempt to copy actions must adjust to the materials they have available. Context can affect results, for example, if the lid of a box gets stuck. That is, even if the observer copies the exact actions of the demonstrator for the same goal, his box might not open. Context can affect goals, for example, if the food at the end of a rake tool is rotten. Then, observers may infer that the demonstrator is not trying to get the food but is attempting to do something else with the rake.

In summary, we have postulated that observers can extract four types of information from demonstrations. Below we review what is known about the use of each of these four elements in children's and apes' social learning.

Human children

Children are clearly interested in the results of demonstrations but if they are presented with results alone – with no demonstration of the actions needed to achieve these results – they often have difficulty reproducing the results (Bellagamba & Tomasello, 1999; Call, Carpenter, & Tomasello, 2005; Huang, Heyes, & Charman, 2002). However, in some tasks they are able to do this, as early as 12 months of age (Tennie, Call, & Tomasello, 2006; Thompson & Russell, 2004). Children's ability to copy others' actions is much easier to demonstrate. Young children often copy the particular way in which an adult achieved a result, even when that way was clearly not causally necessary. For example, Nagell, Olguin, and Tomasello (1993) showed that 2-year-old children copied an adult's flipping or no-flipping actions with a rake, even when that resulted in less efficient performance on their part (see also, e.g., Call et al., 2005; Nielsen, 2006; Whiten, Custance, Gomez, Teixidor, & Bard, 1996). Again, there is evidence that sometimes children copy adults' actions by age 12 months (e.g., Carpenter, Call, & Tomasello, 2005; Nielsen, 2006; Schwier, van Maanen, Carpenter, & Tomasello, 2006).

But children do not always copy others' actions and results. By age 12 months, infants engage in selective imitation, using the other two sources of information, goals and context, to guide their copying. For example, in one study, infants were shown the same actions, for the same result, but the adult's intention varied across conditions. Infants could thus only use an understanding of the adult's intention to solve this problem correctly. Carpenter, Akhtar, and Tomasello (1998) showed 14- to 18-month-olds a series of two

actions on objects, in counterbalanced order. For each object, the two actions were followed by an interesting result, for example, the sudden illumination of colored lights. In the key conditions, one of the demonstrator's actions was marked verbally as intentional ("There!") and one was marked verbally as accidental ("Woops!"), but otherwise the actions looked very similar. Instead of mimicking both actions they saw, even the youngest infants reproduced the actions marked as intentional significantly more often than those marked as accidental. In a third condition, when both actions were marked verbally as intentional, infants typically reproduced both actions.

In another study, infants were not shown the result at all and had to infer it based on the adult's actions and goal. In the key condition, Meltzoff (1995) showed 18-month-olds an adult trying but failing to achieve some result (e.g., the adult's hands pulled on but slipped off the ends of a dumbbell). Infants produced the completed result equally as often in this condition as in a condition in which they saw the adult successfully achieving the result (e.g., pulling apart the two halves of the dumbbell). Infants in the key condition thus understood the adult's unfulfilled goal and produced the result that the adult meant to produce (instead of copying the adult's surface actions such as slipping).

Children's understanding of others' goals can even make imitation of complex tasks possible where it was not before. Carpenter, Call, and Tomasello (2002) have shown that children who did not know what an adult was trying to do as she began her demonstration were unsuccessful on the task themselves, whereas children who did know what she was trying to do – her prior intention – (e.g., through her previous actions on other apparatuses) were successful.

Finally, two further sets of studies illustrate children's use of information about the context and its relation to others' intentions, that is, children's understanding that people choose particular actions (from intentions) for rational reasons. In one set of studies, infants

used information about constraints on the demonstrator to determine whether they should copy an adult's action to achieve a result. Gergely, Bekkering, and Király (2002) showed 14-month-olds an adult touching her head to the top of a box to turn on a light. For half of the infants, the adult's hands were constrained (they were occupied by holding a blanket around her shoulders) and for half of the infants the adult's hands were free. Infants who saw the hands-free demonstration copied the adult's unusual action significantly more often than infants who saw the hands-occupied demonstration. Infants thus appeared to assume that if the adult's hands were free and she still chose to use her head, then there must be a good reason for this choice. However, if the adult's hands were occupied, then the use of her head was explained away as necessary given her circumstances and not an essential part of her action (and thus infants did not reproduce this action). A similar pattern of results was found with 12-month-olds on a different task (Schwier et al., 2006).

In the other set of studies, infants used what was present in the environment to determine which actions they should copy. Bekkering et al. (2000) showed 3- to 6-year-old children an adult touching a table in two locations in turn. In one condition, there were dots on the table in those locations and in another condition there were no dots. In the "no dot" condition, children usually matched the adult's behavior exactly – they even copied her crossed or straight arm positions (because there was no other apparent goal to her actions). In the "dot" condition, however, children touched the same locations as the adult but often did not match her exact arm positions (because there was a clear external goal: touching the dots). Bekkering and colleagues concluded that young children's imitation is guided by their understanding of adults' goals, that is, that there is a hierarchy of goals and subgoals and children imitate what they perceive adults' main goal to be. Sometimes this involves matching adults' actions; sometimes it does not. A similar pattern of results was found with 12-month-olds on a different task (Carpenter et al., 2005).

In summary, by 12 months of age, human infants copy others' actions, goals, and results. Although they have a general tendency to copy the way others do things (their actions), they can override this tendency when necessary, using an understanding of others' goals and the context to interpret others' actions and selectively copy only others' intended or goal-relevant actions.

Nonhuman apes

Mother-reared apes solving problems

Early reports by a number of researchers have cited casual observations to make the point that apes are especially good imitators (e.g., Yerkes & Yerkes, 1929). Some problem-solving experiments in which apes had to use a tool to obtain an out-of-reach reward after seeing a demonstrator solve the problem also provided some support for this view (Haggerty, 1913; Wright, 1978). The results from these studies, however, are difficult to interpret because their procedures were far from rigorous by today's standards. For instance, none of the experimental studies included a control group of apes who had not seen a demonstration, and observation of the demonstrator was on occasion combined with other information such as physically guiding the actions of the subject to foster learning. Consequently, the precise learning mechanisms responsible for success are unclear. In another observational study, Russon and Galdikas (1993, 1995) used a more systematic approach and observed rehabilitant (ex-captive) orangutans to detect cases of copying actions. They reported that the orangutans copied such human behaviors as making fire, painting, washing clothes, and pumping gas. However, although these observations are important for the information they provide about behavioral flexibility and creativity in orangutans, observational data cannot inform us about the specific forms of social learning (if any) responsible for the acquisition of particular behaviors (see Galef, 1985).

Experimental approaches to the study of social learning in mother-reared apes have all used problem-solving tasks in which the apes are shown how to retrieve a food reward. Tomasello and colleagues have conducted several systematic studies with apes and human children to find out which social learning mechanisms underlie problem solving in each species. Tomasello, Davis-Dasilva, Camak, and Bard (1987) presented juvenile and adolescent chimpanzees with a chimpanzee demonstrator who used a T-shaped tool in a two-step sequence to get an out-of-reach reward. Chimpanzee observers benefited from watching the demonstrator and learned to use the tool (compared to a no-demonstration control group that did not learn) but failed to copy the two-step method used by the demonstrator. Tomasello et al. argued that chimpanzees learned about the movements of the tool or the relation between the tool and the food (i.e., emulation learning) but did not learn the movements used by the demonstrator. Nagell et al. (1993) and Call and Tomasello (1994) further investigated this out-of-reach-reward problem with juvenile chimpanzees and human children, and subadult and adult orangutans, respectively. In order to obtain the reward, subjects could use a rake-shaped tool that could be used in two different orientations that resulted in different efficiencies. To one group of subjects, the experimenter demonstrated how to flip the rake to its edge orientation (the more efficient method) and then pulled the rake to bring the reward within her reach. To the other group of subjects, the experimenter simply pulled the rake (already prepositioned in the edge orientation) without flipping it prior to pulling it. Results indicated that apes who witnessed the flipping movement performed it equally as often as apes who did not witness it, and that both groups were equally successful at obtaining the food with the tool (i.e., they copied the result but not the action). The gradual acquisition curves of the most skilled subjects suggested that their techniques developed through individual learning in the form of trial-and-error, not imitative learning. In contrast, children copied the technique (i.e., the actions) that they witnessed.

One potential limitation of the previous studies is that subjects could directly perceive all the elements necessary for solving the problem (out-of-reach food, tool, platform, and their respective spatial relations). Consequently, it can be argued that subjects did not need to pay attention to the demonstrator since individual learning would suffice to solve the problem (note, however, that children did copy the demonstrator). Call and Tomasello (1995) designed a task that addressed this potential limitation and thus highlighted the actions of the demonstrator. They presented juvenile and adult orangutans and three- and four-year-old children with an opaque box with a rod sticking out of it. The rod could be manipulated in three basic ways (pull, push, or rotate, or any combination of these) to obtain a reward located inside the box. After the experimenter demonstrated the correct action (e.g., pulling and rotating) to subjects, subjects were permitted to manipulate the rod to obtain the reward. None of the apes consistently performed above chance – none of them seemed to be copying the demonstrator's actions to solve the problem. Instead, many of them developed preferences through trial-and-error for certain actions and persisted in using them throughout testing. In contrast, children copied the actions performed by the demonstrator to solve the problem. The overall picture arising from these studies is thus that chimpanzees and orangutans (unlike human children) do not copy the actions of others to solve these problems. Instead, they focus on the results of the demonstration and use individual learning to achieve these results themselves.

In a series of studies, Whiten and colleagues have offered a different view to that presented above. They have studied social learning in chimpanzees, gorillas, and orangutans using an innovative approach (Custance, Whiten, Sambrook, & Galdikas, 2001; Stoinski, Wrate, Ure, & Whiten, 2001; Whiten et al., 1996). They presented subjects with a plexiglass box with a piece of food inside. The box was kept closed by two locking devices that had to be removed to gain access to the food, simulating an 'artificial fruit.' An innovation of this

study was that the demonstrated problem-solving activity was complex, and even contained some irrelevant actions. After the human demonstrator demonstrated how to remove the locking devices and opened the box, subjects were offered a baited locked box. The authors reported that chimpanzees and gorillas, but not orangutans, copied some of the demonstrator's actions, for example twisting or pulling one of the locking devices. Whiten and colleagues interpreted these results as evidence that the chimpanzees and gorillas were copying (at least partially) the demonstrator's actions. Tomasello (1996), however, pointed out that even though twisting or not twisting led to the same ultimate result – removal of the locking device and opening of the box – it is still possible that the chimpanzees learned from their observations simply that the device afforded twisting (a kind of lower level result). Apes thus still could have been focusing on the transformations of the box (the results) rather than the actions of the demonstrator in this study.

In an attempt to address these concerns, Horner and Whiten (2005) presented chimpanzees with a box with two holes, one located on top of the box and the other to the side. The top hole was blocked by a bolt and the side hole was blocked by a door. In order to get the reward that was inside the box, subjects needed to insert a stick through the side hole. Inserting the stick into the top hole had no effect on the reward because a partition located inside the box prevented the stick from reaching the reward. The chimpanzees witnessed a human demonstrator removing the bolt, inserting the stick into the top hole, removing the door, inserting the stick into the side hole, and obtaining the reward. The critical manipulation was that in both the demonstration and the response phases, each subject was presented with an opaque and a transparent version of the (otherwise identical) box, in counterbalanced order.

Chimpanzees copied fewer irrelevant actions (poking into the top hole) when they faced the transparent box compared to the opaque box. Horner and Whiten (2005) concluded

that chimpanzees imitated in the opaque box condition, but emulated in the transparent box condition. They attributed the latter finding to the fact that apes had acquired critical causal knowledge by seeing into the transparent box. Furthermore, Horner and Whiten (2005) found that chimpanzees were also likely to copy the actions that had been used for door removal (slide vs. lift). However, some of the same shortcomings mentioned above for the artificial fruit task also apply to this task because the information about actions is mixed with that of results. In particular, sliding the door produced a different result on the box from lifting the door. Moreover, it is still possible that apes inserted the stick into both holes in the opaque box condition for other reasons, such as local enhancement.

Only recently have researchers begun to experimentally separate actions from results, and also to investigate whether apes understand and use the demonstrator's goal in social learning situations. Myowa-Yamakoshi and Matsuzawa (2000) presented chimpanzees with a version of Meltzoff's (1995) test, in which in one condition subjects see only a failed action (the goal) but no result. Whereas Meltzoff (1995) found that 18-month-old children succeeded in this condition as often as in a condition in which they saw a complete, successful demonstration, Myowa-Yamakoshi and Matsuzawa's chimpanzees did not benefit from either demonstration, as evidenced by low rates of opening the boxes after both demonstrations. Call et al. (2005) have focused more systematically on the various sources of information used by chimpanzees and children by presenting subjects with the following three conditions. In one condition, subjects witnessed the full demonstration (action + goal + result), that is, the demonstrator opening a tube with food inside. In another condition, they watched the demonstrator unsuccessfully attempting to open a tube (action + goal). In the third condition, the subjects saw no demonstration but found an already-opened tube lying on the floor (result only). Human children often reproduced the demonstrator's actions and goal. It was not clear whether chimpanzees used the demonstrator's goal: following the

demonstration of an unsuccessful attempt, chimpanzees tried a *different* action than the one demonstrated, but this could have been because they picked up information about the object (it does not open here) instead of the demonstrator's goal. But with regard to actions versus results, again, chimpanzees reproduced mainly the results of the demonstrations. Similar findings were obtained in another study which separated actions and results. Following a method pioneered by Bugnyar and Huber (1997) on marmosets, Tennie et al. (2006) found that great apes failed to copy a demonstrator's method of opening a box (i.e., either by pushing or pulling on its swing door). Although the apes successfully opened the box, their opening style did not match that of the demonstrator (and this was the case in another, 'ghost' condition in which the door was pushed or pulled open in the absence of a demonstrator as well). In contrast, 18- and 24-month-old children copied the opening style of the demonstrator (Tennie et al., 2006).

In summary, there is little evidence of copying of others' actions in mother-reared apes. Instead, many studies show that apes focus on the results of the demonstration and attempt to reproduce them using their own means. Although chimpanzees and possibly orangutans, at least, apparently understand something about others' goals (e.g., Call, Hare, Carpenter, & Tomasello, 2004; Call & Tomasello, 1998), it is not yet clear whether they use this understanding, or an understanding of context, in social learning situations (although see Buttelmann, Carpenter, Call, & Tomasello, 2008, for suggestive new findings with orangutans).

Imitation on command and non-problem-solving tasks

Perhaps one of the most impressive and convincing demonstrations of imitation is imitation on command. There are a handful of studies that have investigated whether apes

can imitate actions on command. Some of the apes in these studies were nursery-reared and some were home-reared or raised in some other human, enculturated environment.

Myowa-Yamakoshi and Matsuzawa (1999) investigated the ability of five human-reared chimpanzees to spontaneously (i.e., before training) imitate a human's arbitrary actions on objects. There were three types of actions: actions on objects (e.g., hitting the bottom of a bowl with the hand), actions on objects directed to the self (e.g., putting a bowl on top of the head), and actions on objects directed at other objects (e.g., placing a ball into a bowl). Myowa-Yamakoshi and Matsuzawa found that chimpanzees rarely reproduced the actions modeled by the experimenter. Moreover, the few behaviors reproduced were all actions on objects directed at other objects. Even after the researchers taught subjects through both modelling and molding (i.e., physically shaping their hands in the right configuration) to reproduce actions, chimpanzees still found actions on objects harder than actions on objects directed toward the self or other objects. Myowa-Yamakoshi and Matsuzawa concluded that object-object (or object-self) interaction was more salient than the demonstrator's motor movements.

We have seen that one of the main problems in deciding whether apes copy actions or results lies in successfully separating the two. Some studies have attempted to do this by blocking some sources of information (e.g., Call et al., 2005; Myowa-Yamakoshi & Matsuzawa, 2000; Tennie et al., 2006) or by substituting the objects on which the demonstration has been carried out for other objects (e.g., Bjorklund, Yunger, Bering & Ragan, 2002). Another approach is to present actions that do not produce changes in the environment, such as hand gestures. There are only a handful of studies of apes that have investigated in a controlled fashion how subjects copy a demonstrator's actions independently from the results that those actions produce. In all of these studies, apes had been specifically trained to reproduce actions on command. Hayes and Hayes (1952)

reported that the home-reared, enculturated chimpanzee Viki reproduced actions (e.g., stretching her mouth with her fingers) on command. In a more controlled study, Custance, Bard, and Whiten (1995) found that two juvenile nursery-reared chimpanzees copied approximately a third of a set of novel actions after several weeks of training. Custance et al. indicated that factors such as whether an action was visible to the subject or whether it involved certain body parts failed to satisfactorily explain why chimpanzees reproduced some actions better than others. However, Call (2001) noted that one of the chimpanzees reproduced more easily those gestures in which there was some body contact (see below).

Two other studies investigated the ability of the enculturated orangutan Chantek to reproduce actions on command. By around 5 years of age, Chantek's caregivers had taught him to play an imitation game, the "Do this" game in which he had to copy the actions his caregivers were producing (Miles, Mitchell, & Harper, 1996). These actions used auditory (e.g., raspberry sounds), visual (e.g., eye-blinking), and kinesthetic modalities (e.g., touching nose). Miles et al. (1996) videotaped 18 episodes of several demonstration-reproduction bouts, for a total of 24 action types. They classified Chantek's reproductions in three different ways depending on the level of accuracy: full imitations (salient aspects of the model were reproduced), partial imitations (less salient aspects of the model were reproduced) and non-imitation (failed to reproduce or produced an inaccurate action). Fifty-six percent of Chantek's reproductions were classified as full imitations, 34% as partial imitations, and 9% as non-imitation.

Some years later, Call (2001; see also Call & Tomasello, 1995) investigated Chantek's ability to reproduce the same set of 48 actions that Custance et al. (1995) used with two chimpanzees. After the experimenter modelled the target action, Chantek was asked to "Do this." In general, Chantek showed good accuracy in reproducing the experimenter's actions. However, three types of errors were especially interesting. First, although he had a

90% matching accuracy between his own gross body areas (e.g., head, arms, body, and legs) and those of the experimenter, Chantek's accuracy decreased considerably for the body parts within those gross body areas. Second, Chantek performed better on actions that involved some contact between his hands and his body compared to non-contact actions – a phenomenon previously described for orangutans, chimpanzees, and gorillas in social learning and sign language acquisition studies (Fouts, 1972; Myowa-Yamakoshi & Matsuzawa, 1999; Patterson, 1978; Shapiro, 1985). Thus, for Chantek and other apes, including the chimpanzees tested by Custance et al. (1995), touching a body part with the index finger is more salient, and easier to reproduce, than simply holding an index finger in the air because there are no tangible results in the second case. Chantek also may have had some difficulty interpreting what he was expected to reproduce. For instance, in the action *raise index finger*, he raised his arm instead of his finger. It could be argued that Chantek perceived the experimenter's goal as raising the arm, not the finger.

In summary, imitating actions on command is difficult for apes. Apes do not do this spontaneously and it is laborious to train. Even trained apes are far from perfect in their responses. The errors they make are interesting and informative in that they, too, suggest that effects on the environment (results) are what apes focus on and choose to reproduce.

Enculturated apes

Ideas about enculturation and its effects on ape development have been around for some time (e.g., Hayes, 1951; Kellogg & Kellogg, 1933). Many different factors – increased exposure to human artifacts, increased interest in and attention to humans, and teaching or scaffolding by humans, to name a few – all might play a role in changing what enculturated apes pay attention to and copy (Call & Tomasello, 1996). And, indeed, there is some

evidence showing that enculturated apes do better on social learning tasks than non-enculturated apes.

First, Hayes and Hayes (1952) compared the ability of an enculturated chimpanzee (Viki), a non-enculturated chimpanzee, and four human children in six problem-solving situations. The problems consisted of obtaining an out-of-reach reward by using a tool or removing some obstacle. Both Viki and the children outperformed the non-enculturated chimpanzee in most problems.

Second, Tomasello, Savage-Rumbaugh, and Kruger (1993) compared the imitative abilities of three enculturated and three non-enculturated bonobos and chimpanzees, and 1.5- and 2.5-year-old human children in an object manipulation task. A human experimenter performed actions such as rolling a paint roller on some clay, grabbing a cloth with pincers, or putting a flour sifter on her head. After each demonstration, the experimenter offered the object to the subject and scored whether the subject reproduced the result of the demonstration (e.g., clay flattened) and/or the actions the experimenter used to achieve that result (e.g., using the roller). Some objects were in a delayed imitation condition, in which the experimenter modelled the action on the object but prevented the subject from acting on the object. Then those objects were presented 48 hours later to see if subjects would remember what they had witnessed. Enculturated apes and children reproduced both the actions and the results of the demonstrations more often than did non-enculturated apes, who rarely reproduced either. Moreover, enculturated apes and children also passed the delayed imitation task, and in fact these apes were better than children on this task.

Recently, Bjorklund and colleagues have investigated the issue of deferred imitation in enculturated apes further. Bering, Bjorklund, and Ragan (2000) allowed subjects (three young enculturated chimpanzees and three enculturated orangutans) to manipulate some objects freely before a human experimenter demonstrated a target action on them (e.g., strike

the bottom of a bowl with a stick, stack some Lego blocks). After a 10-minute delay, subjects had the opportunity to manipulate the objects again and the experimenter asked the apes to do the same thing the experimenter had done. Both chimpanzees and orangutans produced the target actions more often after than before the demonstration (40% compared to 10%). In a follow-up study, Bjorklund, Bering, and Ragan (2000) investigated improvement in deferred imitation in two of these apes (one chimpanzee and one orangutan) two years later. They found some improvement in imitative ability, particularly in the chimpanzee, although the magnitude of the change was not large. The authors argued that apes were copying the actions of others rather than emulating their results.

However, again, a potential criticism of these studies is that actions cannot be separated from results. In the Tomasello et al. (1993) study, too, although actions and results were coded separately, it is nevertheless possible that even the actions could be reproduced by emulation learning, as Tomasello (1996) argued for the studies of Whiten and colleagues discussed above. The same applies in the Bering et al. (2000) study: for instance, striking a drum with a stick involves some motor movements but also some effects in the environment. It is just not clear whether subjects reproduced what the experimenter did (her actions) or what the objects did (the results).

Two studies have addressed this issue with enculturated apes. Bjorklund et al. (2002) did this using a paradigm based on generalization. As in their previous studies, the experimenter demonstrated some actions on objects and after a 10-minute delay asked the subject to reproduce her behavior. However, in this study, during the response period for half of the objects, instead of giving subjects the object on which the experimenter had carried out her demonstration, they gave subjects a different object that shared some of the original object's features. For instance, if the experimenter had used a rake in the demonstration phase, she offered a hoe during the response period. For purposes of comparison, in the other

half of the trials the authors offered the same object that had been used during the demonstration. Results indicated that apes were capable of reproducing the demonstrated behavior even after the original object was substituted by another object. Apes' performance in this condition, however, was worse than when the objects were not exchanged. Bjorklund et al. (2002) interpreted these results as evidence that apes were indeed copying the actions of the demonstrator rather than the effects on objects. However, it is still possible that instead of generalizing actions, subjects were generalizing the results produced.

In the other study, Tomasello and Carpenter (2005) addressed the issue of separating actions and results by coding whether apes reproduced the particular action style an experimenter used to achieve some result. They showed three young nursery-reared chimpanzees a series of demonstrations of actions on objects. The experimenter demonstrated each of the actions with a particular, unnecessary action style that was not the most obvious way to perform the action or achieve the result, for example, she pushed a light panel with her fist instead of her flat hand or rolled a small roller with both hands instead of one. They coded whether chimpanzees reproduced the result and the particular action style the experimenter used. They found that although chimpanzees reproduced the result more often than in a control condition in which the experimenter did not demonstrate any target action (and instead just manipulated the objects), this was not the case for reproducing action style.

Finally, Tomasello and Carpenter (2005) also investigated whether these three chimpanzees could use goals and context as sources of information in a social learning context. Chimpanzees were tested on versions of the Meltzoff (1995) and Carpenter et al. (1998) tests involving imitation of unfulfilled goals and accidental actions discussed above. On both of these tests, these chimpanzees showed the same pattern of results as did children: they completed the unfulfilled action (and did so more often than in a manipulation control

condition) and reproduced more intentional than accidental actions. Because the experimenter's goal differed from the result she achieved in both cases, this suggests that these chimpanzees were using information about the experimenter's goal to determine what to copy. However, in a version of the Gergely et al. (2002) test involving constraints on the demonstrator, as a group these chimpanzees did not differentiate between conditions: they copied the experimenter's use of a tool equally as often when she had to use the tool (because a barrier blocked her from using her hand) as when she freely chose to use the tool (when there was no barrier present). This suggests that they did not consider the context – in the sense of presence or absence of constraints on the demonstrator – in this situation. A different group of enculturated chimpanzees has recently been shown to pass this test, however (Buttelmann, Carpenter, Call, & Tomasello, 2007).

In summary, although at first glance there is some evidence suggesting that enculturated apes may be more likely than other apes to copy actions, more studies are needed to rule out alternate explanations involving reproduction of results. There is evidence that these apes may copy others' goals and even some preliminary evidence of use of the fourth element, context.

Discussion

A relatively clear picture emerges from this review. By their first birthdays, human children gather information about actions, results, goals, and context from demonstrations, and use all of these elements in combination to work out which aspects of the demonstration to copy. In general, children have a tendency to do things the way adults do (i.e., to use the same actions to achieve the same result), but they can override this tendency when there is evidence that the adults did not mean to act in the way they did (i.e., their goal did not match their action or result) or were forced to act in that way by some constraint (i.e., the context).

Apes, in contrast, generally reproduce the results of others' demonstrations. Enculturated apes, at least, may in addition copy others' goals but there is little indisputable evidence that apes of either type copy others' actions.

Why are there such large differences in what apes and children copy? We believe that these differences have roots in fundamental differences between apes and humans in the skills and motivations for participating in activities involving shared intentionality (Tomasello et al., 2005), and thus that they are linked to differences between apes and humans in other, otherwise seemingly unrelated areas which also involve these skills and motivations (see Carpenter, 2006, for a similar argument concerning the imitation of children with autism). More specifically, at the heart of many uniquely human abilities, including joint attentional engagement, declarative pointing, collaborative activities (including collaborative communication), and, as we shall see, certain types of imitation, are two interacting components: 1) an understanding of others' psychological states (e.g., perception and attention, goals and intentions) and 2) a motivation to share psychological states with others. Human infants show evidence of both of these components by age 9-12 months. In contrast, apes, including enculturated apes, apparently have some limited understanding of others' psychological states but little or no motivation to share them (see Behne et al., 2008, for a review).

Both components can influence what one copies from a demonstration. With regard to the first one, apes apparently understand something about others' goals, in the sense of the results that others wish to bring about in the environment (Call et al., 2004). But as yet there is little evidence that non-enculturated apes understand others' intentions, the action plans others choose to achieve their goals (Buttelmann et al., 2008; Tomasello & Carpenter, 2005). If you do not know that someone has chosen a particular action as a means to an end for some reason, you might be unlikely to think that it is important for you to also use that particular

action yourself. In contrast, human infants by 12 months and some enculturated chimpanzees apparently understand both goals and intentions (Buttelmann et al., 2007; Schwier et al., 2006, see Tomasello et al., 2005, for a review), and this may help explain why they are more likely to copy the actions others choose.

More fundamental, perhaps, is the second component, sharing psychological states – and the ability to participate in collaborative activities in general. To see why, first we need to distinguish different types and functions of imitation. Within social learning there are two main types (Carpenter, 2006; Tomasello & Carpenter, 2007). One is actually a process of individual learning in which learners just gather information unilaterally from others. This can be done in an exploitative manner, even when the demonstrator is not aware that the learner is watching. When chimpanzees learn from others how objects work (Tomasello, 1996), they are engaging in this individualistic type of ‘social’ learning. Humans also participate in a second, more collaborative type of learning in which teacher and learner work together to transmit some information (Gergely & Csibra, 2006; Tomasello, Kruger, & Ratner, 1993). It is interesting to note that infants copy others’ actions more often when in this type of ‘pedagogical’ situation than when watching a non-interactive adult perform the same actions from afar, in which case they mostly just reproduce the result the adult achieved (Gergely & Csibra, 2006; Nielsen, 2006). Furthermore, there is some evidence that 1-year-old infants are beginning to see the collaborative structure of some imitative interactions, when they learn actions directed to them and then reverse roles and redirect the actions back to the demonstrator, making it clear by looking to the demonstrator’s face that they see this as a joint activity (Carpenter, Tomasello, & Striano, 2005). Nursery-reared chimpanzees may redirect such learned actions back to their partners, but they do not look to their partner’s face in this way (Tomasello & Carpenter, 2005).

Beyond social *learning*, there are also other reasons for copying others' behavior besides to learn from them, for example to communicate to others that one is like them or sharing something with them (Carpenter, 2006; Užgiris, 1981). Here, copying actions (assuming that the goal matches the result and actions) is crucial, because it marks or makes mutually manifest the correspondence between the two partners. Children's copying of others' actions is related to their tendency to engage in joint attention with others, suggesting a common underlying motivation to communicatively share experiences with others (Carpenter, Savage-Rumbaugh, & Tomasello, 1995; Hobson & Meyer, 2006). There is little evidence of this motivation in apes, in any domain: they do not participate in joint attentional engagement or use declarative gestures such as showing and pointing to share interest in objects or events (e.g., Tomasello & Carpenter, 2005; Tomonaga et al., 2004), and, as we have seen here, they do not copy others' actions (or at least do not do this as pervasively as do human children). It is thus likely that whereas children imitate for both social and instrumental functions (Užgiris, 1981), apes' imitation is only instrumental (Carpenter & Call, 2002; Nielsen, this issue; Tomasello & Carpenter, 2007). We agree with Nielsen (this issue) that this is an matter of motivation rather than competence. For example, apes who have been trained to imitate can do so on command, but they do not then spontaneously transfer these skills to novel contexts (Call & Tomasello, 1995). Also, if it turns out that enculturated apes do copy actions more often than non-enculturated apes, that would suggest that apes (in general) have the capacity to do this, it is just not utilized. Enculturated apes might utilize it more either because they better understand others' intentions along with their goals or because they are more motivated to share experiences with humans (although there is no evidence of this so far; Tomasello & Carpenter, 2005).

Copying the way others do things is especially important in human cultural transmission of beliefs, rituals, and the conventional use of artifacts and language, to name

just a few examples (e.g., Gergely & Csibra, 2006; Tomasello, 1999). In addition, it serves the function of emphasizing cultural identity: not only does it show that imitators understand that ‘you are *like me*’ (Meltzoff, e.g., 2005), but, importantly, it also directly conveys the message to others that “I am *like you*.” Ape culture (Whiten et al., 1999) apparently does not include either of these things. For example, whereas human cultural differences are often completely arbitrary in the sense that there is no a priori reason for individuals of a culture to do things the way they do except conventionality, the differences observed among ape groups (see, e.g., van Schaik et al., 2003; Whiten et al., 1999) are much more tied to the physical environment. First, they are grounded to a greater extent on ecological problems having to do with extractive foraging and tool use. Second, some of the best examples of variation between groups may be a direct result of the particular ecological conditions at each site, for example the behavior of the ants that live there (Humble & Matsuzawa, 2002; Tomasello, 1990). In apes there is a surprising absence of inter-group differences in things like gestures, particularly non-transitive ones, which are a category of behaviors that are virtually free of ecological constraints (see Call & Tomasello, 2007, for a review). All this fits well with the general finding that apes reproduce others’ results without copying their actions.

However, while there are obvious advantages to copying others’ actions, there are also some disadvantages. If we all only copied each other, there would be no innovation, and no ability to adapt to different circumstances or changes in the environment. We believe that a successful balance between copying actions and reproducing results – one that allows learners to flexibly and selectively copy others’ actions when needed – requires an understanding of others’ goals and intentions (i.e., how others choose action plans to achieve their goals based on consideration of the context), something human infants already possess by their first birthdays.

Acknowledgements

Parts of this paper were previously published in the journal *Infancia y Aprendizaje* (Call & Carpenter, 2003, **26**(3), 325-349). We gratefully acknowledge the Fundación Infancia y Aprendizaje for granting us permission to reproduce them in this article.

References

- Behne, T., Carpenter, M., Gräfenhain, M., Liebal, K., Liszkowski, U., Moll, H., Rakoczy, H., Tomasello, M., Warneken, F., & Wyman, E. (2008). Cultural learning and creation. To appear in U. Müller, J. Carpendale, N. Budwig, & B. Sokol (Eds.), *Social life and social knowledge: Toward a process account of development* (pp. 65-101). New York: Lawrence Erlbaum.
- Bekkering, H., Wohlschläger, A., & Gattis, M. (2000). Imitation of gestures in children is goal-directed. *Quarterly Journal of Experimental Psychology*, 53A, 153-164.
- Bellagamba, F., & Tomasello, M. (1999). Re-enacting intended acts: Comparing 12- and 18-month-olds. *Infant Behavior and Development*, 22, 277-282.
- Bering, J.M. (2004). A critical review of the “enculturation hypothesis”: The effects of human rearing on great ape social cognition. *Animal Cognition*, 7, 201-212.
- Bering, J.M., Bjorklund, D.F. & Ragan, P. (2000). Deferred imitation of object-related actions in human-reared juvenile chimpanzees and orangutans. *Developmental Psychobiology*, 36, 218-232.
- Bjorklund, D.F., Bering, J.M. & Ragan, P. (2000). A two-year longitudinal study of deferred imitation of object manipulation in a juvenile chimpanzee (*Pan troglodytes*) and orangutan (*Pongo pygmaeus*). *Developmental Psychobiology*, 37, 229-237.
- Bjorklund, D.F., Yunger, J.L., Bering, J.M. & Ragan, P. (2002). The generalization of deferred imitation in enculturated chimpanzees (*Pan troglodytes*). *Animal Cognition*, 5, 49-58.
- Bugnyar, T. & Huber, L. (1997). Push or pull: An experimental study on imitation in marmosets. *Animal Behaviour*, 54, 817-831.
- Buttelmann, D., Carpenter, M., Call, J., & Tomasello, M. (2007). Enculturated chimpanzees imitate rationally. *Developmental Science*, 10, F31-F38.

- Buttelmann, D., Carpenter, M., Call, J., & Tomasello, M. (2008). Rational tool use and tool choice in human infants and great apes. *Child Development, 79*, 609-626.
- Call, J. (1999). Levels of imitation and cognitive mechanisms in orangutans. In S.T. Parker, R.W. Mitchell & H.L. Miles (eds.). *Mentalities of gorillas and orangutans* (pp 316-341). New York: Cambridge University Press.
- Call, J. (2001). Body imitation in an enculturated orangutan. *Cybernetics and Systems, 32*, 97-119.
- Call, J. & Carpenter, M. (2002). Three sources of information in social learning. In K. Dautenhahn & C. Nehaniv (Eds.). *Imitation in animals and artifacts* (pp. 211-228). Cambridge, MA: MIT Press.
- Call, J., & Carpenter, M. (2003). On imitation in apes and children. *Infancia y Aprendizaje, 26*, 325-349.
- Call, J., Carpenter, M., & Tomasello, M. (2005). Copying results and copying actions in the process of social learning: Chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). *Animal Cognition, 8*, 151-163.
- Call, J., Hare, B., Carpenter, M., & Tomasello, M. (2004). 'Unwilling' versus 'unable': Chimpanzees' understanding of human intentions. *Developmental Science, 7*, 488-498.
- Call, J. & Tomasello, M. (1994). The social learning of tool use by orangutans (*Pongo pygmaeus*). *Human Evolution, 9*, 297-313.
- Call, J. & Tomasello, M. (1995). The use of social information in the problem-solving of orangutans (*Pongo pygmaeus*) and human children (*Homo sapiens*). *Journal of Comparative Psychology, 109*, 308-320.
- Call, J. & Tomasello, M. (1996). The effect of humans on the cognitive development of apes. In A. E. Russon, K. A. Bard, & S. T. Parker (Eds.), *Reaching into thought* (pp. 371-403). New York: Cambridge University Press.

- Call, J. & Tomasello, M. (1998). Distinguishing intentional from accidental actions in orangutans (*Pongo pygmaeus*), chimpanzees (*Pan troglodytes*), and human children (*Homo sapiens*). *Journal of Comparative Psychology*, *112*, 192-206.
- Call, J. & Tomasello, M. (2007). The gestural repertoire of chimpanzees (*Pan troglodytes*). In J. Call & M. Tomasello (eds.), *Gestural communication in apes and monkeys* (pp 17-39). Mahwah, NJ: LEA.
- Carpenter, M. (2006). Instrumental, social, and shared goals and intentions in imitation. In S. J. Rogers & J. Williams (Eds.), *Imitation and the development of the social mind: Lessons from typical development and autism* (pp. 48-70). New York: Guilford.
- Carpenter, M., Akhtar, N. & Tomasello, M. (1998). Fourteen through 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behavior & Development*, *21*, 315-330.
- Carpenter, M. & Call, J. (2002). The chemistry of social learning. *Developmental Science*, *5*, 22-24.
- Carpenter, M., Call, J., & Tomasello, M. (2002). Understanding 'prior intentions' enables 2-year-olds to imitatively learn a complex task. *Child Development*, *73*, 1431-1441.
- Carpenter, M., Call, J., & Tomasello, M. (2005). Twelve- and 18-month-olds copy actions in terms of goals. *Developmental Science*, *8*, F13-F20.
- Carpenter, M., Tomasello, M., & Savage-Rumbaugh, S. (1995). Joint attention and imitative learning in children, chimpanzees, and enculturated chimpanzees. *Social Development*, *4*, 217-237.
- Carpenter, M., Tomasello, M., & Striano, T. (2005). Role reversal imitation and language in typically-developing infants and children with autism. *Infancy*, *8*, 253-278.

- Custance, D. M., Whiten, A., & Bard, K. A. (1995). Can young chimpanzees (*Pan troglodytes*) imitate arbitrary actions? Hayes & Hayes (1952) revisited. *Behaviour*, *132*, 837-859.
- Custance, D.M., Whiten, A., Sambrook, T. & Galdikas, B. (2001). Testing for social learning in the "artificial fruit" processing of wildborn orangutans (*Pongo pygmaeus*), Tanjung Puting, Indonesia. *Animal Cognition*, *4*, 305-313.
- Fouts, R.S. (1972). Use of guidance in teaching sign language to a chimpanzee (*Pan troglodytes*). *Journal of Comparative Psychology*, *80*, 515-522.
- Gergely, G., Bekkering, H., & Király, I. (2002). Rational imitation in preverbal infants. *Nature*, *415*, 755.
- Gergely, G., & Csibra, G. (2006). Sylvia's recipe: Human culture, imitation, and pedagogy. In N. Enfield & S. Levinson (Eds.), *The roots of human sociality: Culture, cognition, and interaction* (pp. 229-255). Oxford: Berg.
- Haggerty, M.E. (1913). Plumbing the minds of apes. *McClure's Magazine*, *41*, 151-154.
- Hayes, C. (1951). *The ape in our house*. New York: Harper.
- Hayes, K. J. & Hayes, C. (1952). Imitation in a home-raised chimpanzee. *Journal of Comparative Psychology*, *45*, 450-459.
- Heyes, C.M., & Ray, E.D. (2002). Distinguishing intention-sensitive from outcome-sensitive imitation. *Developmental Science*, *5*, 34-36.
- Hobson, R. P., & Lee, A. (1999). Imitation and identification in autism. *Journal of Child Psychology and Psychiatry*, *40*, 649-659.
- Hobson, R. P., & Meyer, J. (2006). Imitation, identification, and the shaping of mind: Insights from autism. In S. J. Rogers & J. Williams (Eds.), *Imitation and the development of the social mind: Lessons from typical development and autism* (pp. 198-224). New York: Guilford.

- Horner, V. & Whiten, A. (2005): Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*). *Animal Cognition*, 8, 164-181.
- Huang, C., Heyes, C., & Charman, T. (2002). Infants' behavioral re-enactment of "failed attempts": Exploring the roles of emulation learning, stimulus enhancement, and understanding of intentions. *Developmental Psychology*, 38, 840-855.
- Humle, T. & Matsuzawa, T. (2002). Ant-dipping among the chimpanzees of Bossou, Guinea, and some comparisons with other sites. *American Journal of Primatology*, 58, 133-148.
- Kellogg, W.N. & Kellogg, L.A. (1933). *The ape and the child*. New York: McGraw-Hill.
- Meltzoff, A. N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology*, 31, 1-16.
- Meltzoff, A. N. (2005). Imitation and other minds: The "like me" hypothesis. In S. Hurley & N. Chater (Eds.), *Perspectives on imitation: From neuroscience to social science*, Volume 2 (pp. 55-77). Cambridge, MA: MIT Press.
- Miles, H.L., Mitchell, R.W. & Harper, S.E. (1996). Simon says: The development of imitation in an enculturated orangutan. In A.E. Russon, K.A. Bard & S.T. Parker (Eds.). *Reaching into thought* (pp. 278-299). Cambridge: Cambridge University Press.
- Myowa-Yamakoshi, M. & Matsuzawa, T. (1999). Factors influencing imitation of manipulatory actions in chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology*, 113, 128-136.
- Myowa, M., & Matsuzawa, T. (2000). Imitation of intentional manipulatory actions in chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology*, 114, 381-391.
- Nagell, K., Olguin, R., & Tomasello, M. (1993). Processes of social learning in the tool use of chimpanzees (*Pan troglodytes*) and human children (*Homo sapiens*). *Journal of Comparative Psychology*, 107, 174-186.

- Nielsen, M. (2006). Copying actions and copying outcomes: Social learning through the second year. *Developmental Psychology, 42*, 555-565.
- Patterson, F. (1978). Linguistic capabilities of a lowland gorilla. In F.C.C. Peng (Ed.). *Sign language and language acquisition in man and ape* (pp. 161-201). Boulder, Colorado: Westview Press.
- Russon, A.E. & Galdikas, B.M.F. (1993). Imitation in free-ranging rehabilitant *orangutans* (*Pongo pygmaeus*). *Journal of Comparative Psychology, 107*, 147-161.
- Russon, A.E. & Galdikas, B.M.F. (1995). Constraints on great apes' imitation: Model and action selectivity in rehabilitant orangutan (*Pongo pygmaeus*) imitation. *Journal of Comparative Psychology, 109*, 5-17.
- Schwier, C., van Maanen, C., Carpenter, M., & Tomasello, M. (2006). Rational imitation in 12-month-old infants. *Infancy, 10*, 303-311.
- Searle, J. R. (1983). *Intentionality: An essay in the philosophy of mind*. Cambridge, UK: Cambridge University Press.
- Shapiro, G.L. (1985). Factors influencing the variance in sign learning performance by four juvenile orangutans (*Pongo pygmaeus*). Unpublished doctoral dissertation. University of Oklahoma.
- Stoinski, T.S., Wrate, J.L., Ure, N. & Whiten, A. (2001). Imitative learning by captive western lowland gorillas (*Gorilla gorilla gorilla*) in a simulated food-processing task.. *Journal of Comparative Psychology, 115*, 272-281.
- Tennie, C., Call, J. & Tomasello, M. (2006). Push or pull: imitation versus emulation in human children and great apes. *Ethology, 112*, 1159-1169.
- Thompson, D. E., & Russell, J. (2004). The ghost condition: Imitation versus emulation in young children's observational learning. *Developmental Psychology, 40*, 882-889.

- Tomasello, (1990). Cultural transmission in the tool use and communicatory signalling in chimpanzees? In S.T. Parker & K.R. Gibson (eds.). "Language" and intelligence in monkeys and apes (pp. 274-311). Cambridge: Cambridge University Press.
- Tomasello, M. (1996). Do apes ape? In Heyes, C.M. & Galef, B.G.Jr. (Eds.). *Social learning in animals: The roots of culture* (pp. 319-346). New York: Academic Press.
- Tomasello, M., & Call, J. (2004). The role of humans in the cognitive development of apes revisited. *Animal Cognition*, 7, 213-215.
- Tomasello, M., & Carpenter, M. (2005). The emergence of social cognition in three young chimpanzees. *Monographs of the Society for Research in Child Development*, 70 (1, Serial No. 279).
- Tomasello, M., & Carpenter, M. (2007). Shared intentionality. *Developmental Science*, 10, 121-125.
- Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The ontogeny and phylogeny of cultural cognition. *Behavioral and Brain Sciences*, 28, 675-735.
- Tomasello, M., Davis-Dasilva, M., Camak, L., & Bard, K. (1987). Observational learning of tool-use by young chimpanzees. *Human Evolution*, 2, 175-183.
- Tomasello, M., Kruger, A. C., & Ratner, H. H. (1993). Cultural learning. *Behavioral and Brain Sciences*, 16, 495-552.
- Tomasello, M., Savage-Rumbaugh, E. S. & Kruger, A. C. (1993). Imitative learning of actions on objects by children, chimpanzees, and enculturated chimpanzees. *Child Development*, 64, 1688-1705.
- Tomonaga, M., Myowa-Yamakoshi, M., Mizuno, Y., Yamaguchi, M., Kosugi, D., Bard, K., Tanaka, M., Matsuzawa, T. (2004). Development of social cognition in infant

- chimpanzees (*Pan troglodytes*): Face recognition, smiling, gaze and the lack of triadic interactions. *Japanese Psychological Research* 46, 227-235.
- Užgiris, I. C. (1981). Two functions of imitation during infancy. *International Journal of Behavioral Development*, 4, 1-12.
- 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, 102-105.
- Want, S. C., & Harris, P. L. (2002). How do children ape? Applying concepts from the study of non-human primates to the developmental study of 'imitation' in children. *Developmental Science*, 5, 1-13.
- Whiten, A., Custance, D. M., Gómez, J. C., Teixidor, P., & Bard, K. A. (1996). Imitative learning of artificial fruit processing in children (*Homo sapiens*) and chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology*, 110, 3-14.
- 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.
- Whiten, A. & Ham, R. (1992). On the nature and evolution of imitation in the animal kingdom: Reappraisal of a century of research. In P. J. B. Slater, J. S. Rosenblatt, C. Beer, & M. Milinsky (Eds.). *Advances in the study of behavior* (pp. 239-283). New York: Academic Press.
- Wright, R.V.S. (1978). Imitative learning of a flaked stone technology -The case of an orangutan. In S.L. Washburn & E.R. Mccown (Eds.). *Human evolution. Biosocial perspectives* (pp. 214-236). Menlo Park, California: The Benjamin/Cummings Publishing Company.

Yerkes, R.M. & Yerkes, A.W. (1929). *The great apes. A study of anthropoid life.* (3rd. 1945)

(Vol. 20). New Haven, Connecticut: Yale University Press.

Zentall, T. R. (1996). An analysis of imitative learning in animals. In Heyes, C. M. & Galef,

B. G. Jr. (Eds.). *Social learning in animals: The roots of culture* (pp. 221-243). New

York: Academic Press.