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9 Three Sources of Information in Social Learning

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9.1 Three Sources of Information in Social Learning

Recent years have seen an unprecedented interest in the topic of social learning in animals. This interest is clearly illustrated by the increasing number of species investigated (e.g., dolphins: Herman, chapter 3 of this volume; parrots: Moore 1996; Pepperberg, chapter 4 of this volume; orangutans: Call and Tomasello 1994a, 1995), the new research methods used (Call and Tomasello 1995; Heyes and Dawson 1990; Whiten et al. 1996), and the new mechanisms that have been described (emulation: Tomasello 1990; goal emulation: Whiten and Ham 1992; program-level imitation: Byrne 1994; string-parsing imitation: Byrne 1999). Different theoretical approaches, from behaviorism to cognitivism, continue to contribute to this fast-growing field.

Although so much research activity is clearly a sign of progress and good health for the field, progress also has its risks. First, some theoretical terms have become too broad or too narrow. For instance, the term *imitation* is used with different meanings by different researchers. While some researchers use it in a general way to denote copying behavior (e.g., Meltzoff and Moore 1989), others prefer to reserve it for those cases in which the organism not only copies behavior but also acquires novel behavior (Thorpe 1956; Zentall 1996). Second, whereas these terms are useful for characterizing the types of social learning mechanisms different species (or children of different ages) tend to use, they are not as helpful when it comes to identifying specific instances of social learning. For example, imitation (with all that the term implies; see below) is assumed when human children reproduce others' behavior, but other mechanisms may be at work in any given instance. Finally, some mechanisms tend to overshadow others, occupying a disproportionate share of research attention. For instance, Matheson and Fragaszy (1998) recently pointed out that too much research attention is devoted to investigating imitation—copying the exact behavioral patterns of a demonstrator—while other mechanisms that may be more relevant to the species' survival are neglected.

One mechanism that, in our opinion, has begun to suffer some of the same problems that have plagued the term *imitation* is emulation. This chapter attempts to remedy this situation to some extent by clarifying the different types of emulation available and by making clear its relation to other social learning mechanisms, especially imitation. We then present a new framework for investigating social learning that is based on focusing on the different types of information that observers are able to extract from models. Finally, we explore the advantages of adopting such a framework for the study of social learning in both animals and artifacts.

9.2 Emulation and Imitation

Traditionally, three main social learning mechanisms have been used to explain an observer's acquisition of some part of the behavioral repertoire of a demonstrator (social learning mechanisms in the sense of Whiten and Ham 1992). These three mechanisms are: stimulus or local enhancement (Spence 1937; Thorpe 1956), observational conditioning (Mineka and Cook 1988), and true imitation (Thorpe 1956). Stimulus enhancement refers to the observer's attention being attracted to a particular aspect of the situation. For instance, when a chimpanzee uses a hammer to crack open a nut, other animals may be attracted to the hammer or the anvil on which the nut was cracked. This attraction, however, does not produce any specific learning; it simply puts observers in an advantageous position to learn individually. Observational conditioning consists of learning about some relation between two stimuli by watching another animal. It is not learning about the response itself, which is already in the behavioral repertoire of the observer. For instance, an observer may learn to avoid snakes upon seeing a conspecific's avoidance responses (Mineka and Cook 1988). Neither of the previous two mechanisms, however, involves learning about the precise behavior of a demonstrator. In contrast, true imitation consists of acquiring a behavior by copying the demonstrator's behavior. The observer acquires the motor movements that are needed to solve a problem. For instance, a child may learn to use the same movements as adults to operate a machine after observing an adult do so.

Tomasello and colleagues (1987; see also Tomasello 1990) added a fourth mechanism called *emulation* to account for some chimpanzee tool use results that could not be accounted for by any of

the previous three social learning mechanisms. In this study, three different groups of chimpanzees were presented with three experimental conditions. The first group observed a chimpanzee demonstrator using a stick to retrieve a reward situated on a platform. The second group observed a chimpanzee demonstrator manipulating the tool without the reward being present. The third group did not observe any demonstrator. Chimpanzees that observed the demonstrator using the tool to obtain the reward clearly benefited from this experience because they obtained the reward faster than either of the other two groups of chimpanzees. Yet the successful chimpanzees used a different tool technique from the demonstrator. Thus, chimpanzees learned something from the demonstrator, but did not copy her precise motor patterns (i.e., actions). This was clearly different from either local enhancement or observational conditioning because subjects learned something more specific than the context or the particular stimuli involved, but it did not qualify as true imitation because subjects did not copy the actions of the demonstrator.

Tomasello (1990, 1996) used the term *emulation* to describe this type of social learning and contrasted emulation with imitation on the basis of two main parameters: type of information copied and sensitivity to the demonstrator's intentions. In regard to the information copied, emulation is based on reproducing the results of a demonstrator's actions, whereas imitation is based on copying the actions that brought about those results. In other words, emulation involves reproducing changes in the state of the environment that are a result of the demonstrator's behavior, whereas imitation involves reproducing the actions that produced those changes in the environment. To illustrate, when a demonstrator cracks open a nut with a hammer, emulation would consist of reproducing the cracked-open nut independently of the actions used by the demonstrator, for instance, by biting into it to open it. In contrast, imitation would consist of copying the demonstrator's hammering actions to open the nut.

In regard to the sensitivity to intentions, Tomasello (1990; see also Tomasello, Kruger, and Ratner 1993) argued that reproducing results (i.e., emulation) does not necessarily imply an understanding of what the demonstrator's goals or intentions are. The observer may simply look at the changes that occur in the environment and recreate them with its own skills. In a sense, the observer reinvents the actions that are needed to solve the problem. In contrast,

Tomasello (1990) argued that when imitating, observers copy the actions of a demonstrator because they understand that the demonstrator used those actions with a certain goal in mind. However, Tomasello, Kruger, and Ratner (1993) also distinguished a type of social learning in which observers copy the actions of a demonstrator without understanding the demonstrator's goals: mimicry.

Recent data have blurred the distinction between emulation, imitation, and mimicry in three main ways. First, emulation has been given different meanings. Whereas Tomasello (1990, 1996) argued that emulation was about copying results, Whiten and Ham (1992) coined the term *goal emulation* to indicate reproduction of the end result of a demonstrator's actions *with* an understanding of the demonstrator's goal. As a consequence, one type of emulation implies some sensitivity to intentions in the form of goals whereas the other does not.

Second, in any given instance of social learning, it is difficult to determine which mechanism is being used. For example, Zentall, Sutton, and Sherburne (1996; see also Kaiser, Zentall, and Galef 1997) have presented evidence of pigeons copying a demonstrator's motor patterns in a problem-solving situation, but it is unclear from that instance which mechanism the birds used. If they understood the demonstrator's goal, we can credit the birds with imitation; if not, we should call their behavior mimicry. At this point, it is difficult, if not impossible, to distinguish between imitation and mimicry within a given instance of reproduction of a demonstrator's straightforward, "normal" behavior (although see Carpenter, Nagell, and Tomasello 1998 for an attempt to do this). At the present time, we must use outside evidence of understanding of others' intentions (from experiments that test this understanding directly, e.g., Call and Tomasello 1998; Carpenter, Akhtar, and Tomasello 1998; Meltzoff 1995) to hypothesize about which mechanisms organisms may be using.

Finally, although in the case of mimicry it is possible that reproduction of a demonstrator's actions may not imply understanding of others' goals, the converse is also possible: in some cases, *not* reproducing the demonstrator's actions exactly has been taken as evidence of understanding of intentions. For instance, in a study of imitation of others' unfulfilled intentions, Meltzoff (1995) showed that children do not always copy a demonstrator's actions exactly when they know what the goal is—instead, they reproduce what the adult meant to do. Likewise, Carpenter, Akhtar, and Tomasello

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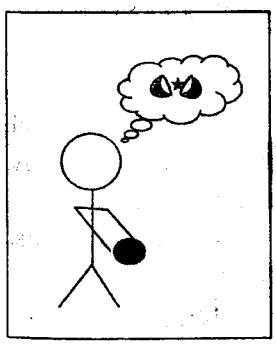

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The danger here is that the terms for the different social learning mechanisms will lose their usefulness since there is not always a clear distinction between imitation, emulation, and mimicry. To remedy this situation, we suggest restricting the use of these terms to developmental or comparative discussions of which mechanisms different-aged children or different species are capable of or tend to use. For considering individual instances of social learning, we propose a new, multidimensional framework that encompasses the different types of information that observers are able to extract from demonstrators.

9.3 A New, Multidimensional Framework

The main idea behind a multidimensional framework is that a demonstrator's model produces several sources of information simultaneously and observers may selectively attend to some of these sources but not others. An analogy will help to clarify this point. When we burn wood, at least three products are released: light, heat, and smoke. Each of these products occurs simultaneously. Similarly, a demonstrator's model releases at least three products: goals, actions, and results (figure 9.1). Goals are the dem-

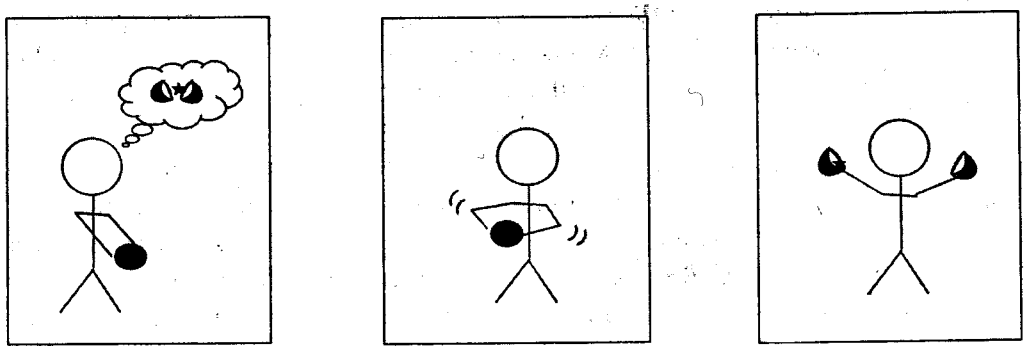

Figure 9.1 The different sources of information in a social learning situation. In this demonstration, the demonstrator opens a plastic Easter egg and gets the prize that is inside. Note that there are often several hierarchically organized goals (get the prize, open the egg, pull the egg apart), actions (pull on the egg, take the prize), and results (the egg is open, the egg is in two pieces, the prize is available).

onstrator's aim, the final state of affairs that she wants to bring about. Actions are the motor patterns the demonstrator uses to bring about those results. Results are changes in the environment that are a consequence of the demonstrator's actions. These three types of information are hierarchically organized, since goals dictate actions and actions determine the results.

Sources of Information: Independence and Interrelations

It is important to consider all three sources of information—both independently and in relation to each other—in each instance of social learning. By doing so, we can avoid mistakes and explain a greater variety of results. Figure 9.2 presents all the possible combinations of goals, actions, and results, along with the theoretical terms associated with each combination. We hope this figure helps make the following points about the importance of considering the sources of information separately.

First, because the three sources of information are independent of each other, it is important not to use one source as an automatic indication or predictor of another. For instance, copying actions should not be taken as evidence of understanding of goals: observers may copy a demonstrator's actions with or without an understanding of why the demonstrator is performing those actions. Conversely, understanding of goals cannot be used to predict copying actions: observers may be able to infer the goals of a demonstrator but then choose to use their own behavioral repertoire to solve a problem. Moreover, individuals may understand goals but choose not to adopt them, instead copying the actions and reproducing the results for a different goal.[1] In order to figure out which of the sources is being used, the sources should be tested directly, not simply inferred from the presence or absence of other sources of information. Two possible methods of investigating the sources of information used by subjects consist of eliminating some of the sources but not others (e.g., demonstrating only the goal; Meltzoff 1995) or making one of the sources ambiguous and seeing how alternative interpretations of that source affect the others (e.g., demonstrating the same action twice, each time with different goals; Bekkering, Wohlschläger, and Gattis, 2000).

Second, another advantage of focusing on the particular sources of information independently is that false positives can be more

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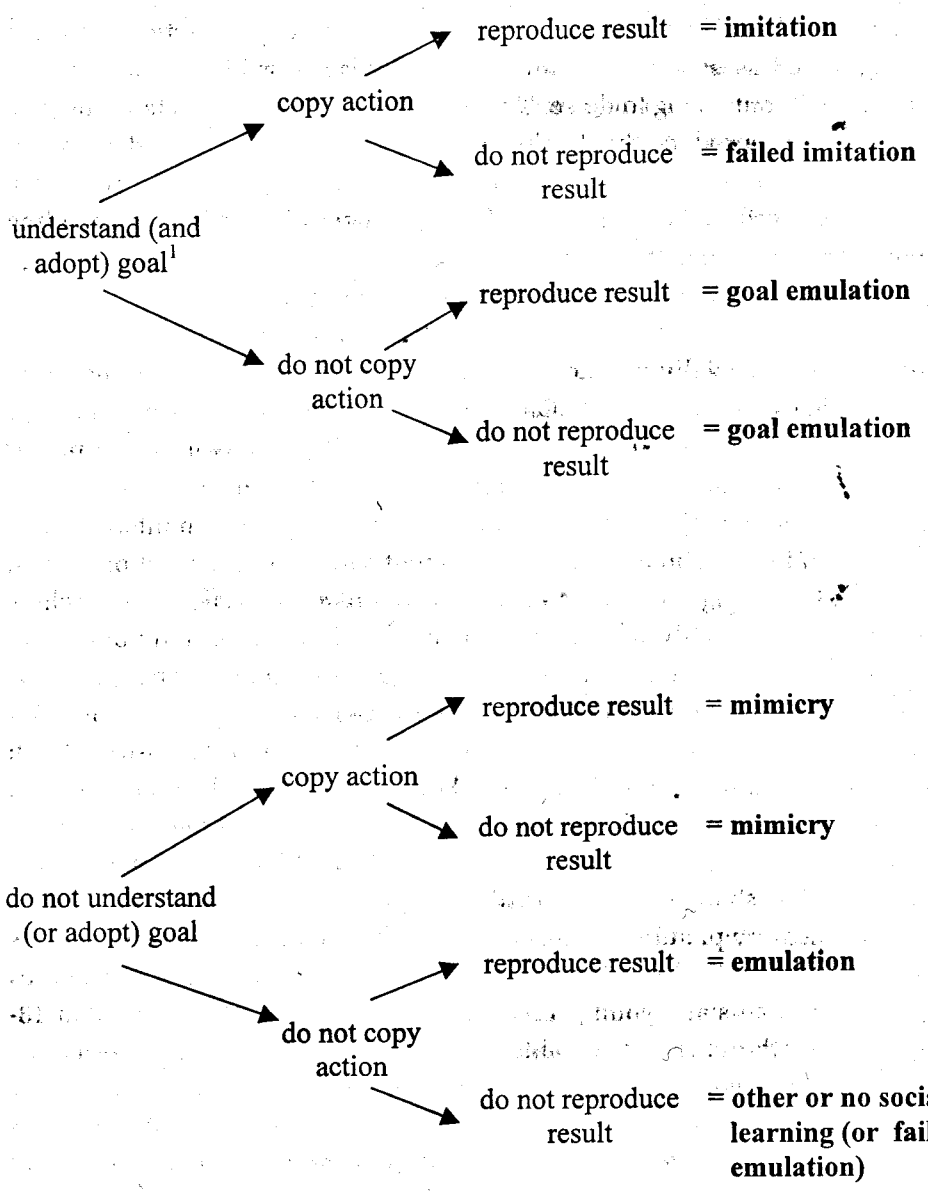

Figure 9.2 The three sources of information with the theoretical terms associated with each combination.

readily detected. For instance, although copying actions is often used as evidence of imitation, it is also possible to copy actions without trying to do so. That is, observers may understand the goal and reproduce the results using the same action as the demonstrator but they could have used the same actions just by convergence since they have similar behavioral repertoires, without attending to the demonstrator's actions at all. Or, observers could copy the demonstrator's actions without intending to reproduce the result but achieve the result anyway. These types of coincidental results are especially probable in studies that use relatively simple problems in the models. Only carefully designed experimental tests that examine each source separately will help avoid these potential problems.

On the other hand, we must also keep in mind the interrelations and interactions among the different sources of information. Often, depending on their interests and population of study, researchers focus on only one of the sources of information, individually, to the relative exclusion of the others. For example, comparative psychologists often focus on whether organisms copy the actions of a demonstrator exactly (e.g., Nagell, Olguin, and Tomasello 1993; Call and Tomasello 1994a, 1995; Whiten et al. 1996; Zentall, Sutton, and Sherburne 1996), without testing whether they understand the goals of the demonstrator. However, focusing on only one of the sources at a time is likely to produce an incomplete and fragmentary picture. For instance, by focusing only on copying actions it would be difficult to explain the findings of several recent studies of infants and young children. First, Meltzoff (1995) found that 18-month-old infants are able to complete unfulfilled actions—actions they have never seen performed in entirety—as easily as they copy fulfilled ones. Second, when accidental (Carpenter, Akhtar, and Tomasello 1998) and incidental (Bekkering, Wohlschläger, and Gattis 2000) actions are included in a demonstration, children differentially disregard those actions and copy only the actions that were performed intentionally or that they consider to be goal related. If children were simply copying the demonstrators' actions, they should have copied the experimenter's failed attempts in Meltzoff's study and the accidental and incidental actions in the Carpenter, Akhtar, and Tomasello and Bekkering, Wohlschläger, and Gattis studies along with the intentional ones. These results can only be explained by considering the interaction of goals and actions.

We know far less about the interaction between different types of information such as goals and results. As discussed above, it is possible to reproduce the results of a demonstrator with or without understanding the demonstrator's goals (goal emulation vs. emulation, respectively). Although most evidence seems to indicate that apes, for example, tend to copy things other than actions from a model (i.e., they use emulation), it is still not clear whether they focus on results (emulation: Call and Tomasello 1994a, 1995; Nagell, Olguin, and Tomasello 1993) or goals (goal emulation: Whiten and Ham 1992). Future research will be needed to resolve this issue. In short, a multidimensional focus is particularly important when attempting to determine what social learning mechanisms are responsible for the acquisition of novel behavior.

Shifting between Sources of Information

Not only do the different sources of information interact, but the emphasis on one or the other (or a combination of them) may shift during a given demonstration. During the course of learning a task, observers may use different types of information from a demonstrator. This is clearly illustrated if we consider the interaction between information acquired through social observation and information acquired through individual practice during problem solving. Strictly speaking, purely observational learning should occur in the first trial without hesitation and producing a complete response. In practice, most of the time even fast learners take a few trials to optimize their behavior to find a solution, during which time the information gathered through observation is constantly combined with the information gathered from practice with the problem.

The problem of the interaction between observational and experiential information is complicated further when we consider that observational information can be of at least three different kinds: goals, actions, and results. With this in mind, it is easy to see that observers may potentially attend to different types of information depending on their previous success or failure, or the information that they gathered from applying their newly acquired information, or both. For example, it is a common experience among adult humans to watch someone achieve some result (e.g., with a new tool, or when learning to play a new sport or musical instrument) and then to attempt to reproduce that result oneself. If one's first

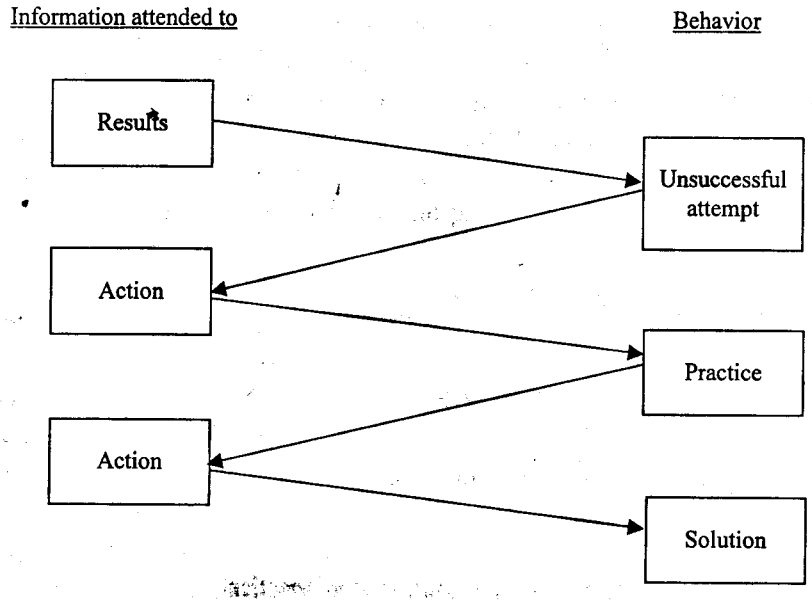

Figure 9.3 Shifting between sources of information in a social learning task.

attempt is unsuccessful, during the next demonstration one might pay more attention to the demonstrator's actions than to the end result (figure 9.3). Following such an occurrence, when an observer first attends to the results of a demonstration, and then on the next trial attends to the demonstrator's actions, are we justified in claiming that the observer has learned through emulation or imitation? It seems to us that one solution is to focus on a unit of information that the existing social learning mechanisms, such as emulation and imitation, do not capture. In other words, emulation and imitation are tools that are too blunt to do the job. A finer tool is required, one that breaks down the behavior of the demonstrator into its constituent pieces: goals, actions, and results.

Developing the Ability to Exploit Various Sources of Information

Human children are capable of using the three types of information (goals: Meltzoff 1995; actions: Nagell, Olguin, and Tomasello 1993; results: Bellagamba and Tomasello 1999). How their predispositions change over time and how they come to use each of these sources are still unanswered questions that will require further research. One possibility we favor is that young infants are primarily predisposed to attend and to reproduce actions. This idea is sup-

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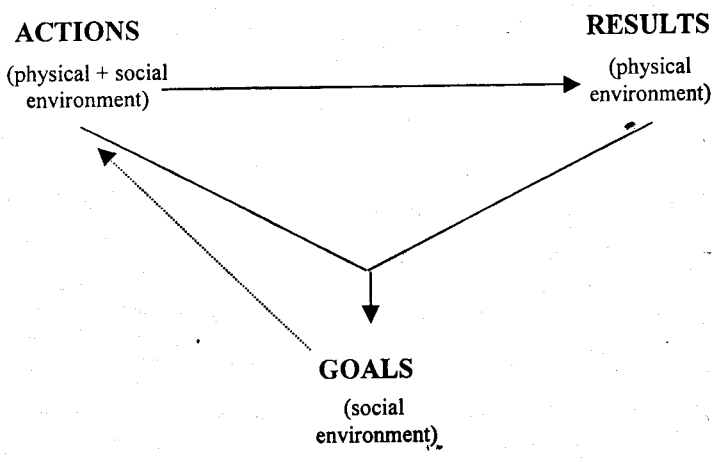

Figure 9.4 Children learn about goals and results from observing others' actions.

ported by the evidence on neonatal imitation and the ease and pleasure with which young infants and children engage in imitative games (Meltzoff 1996). We argue that this tendency to attend to and reproduce the actions of others may contribute significantly to infants' discovery of the two other types of information that emanate from models: results and goals (figure 9.4). In other words, by copying the actions of other people, infants may discover interesting things about both their physical and their social environments. They may learn how objects work, how to produce changes in the environment, and about physical causality by observing and copying the consequences and cause-and-effect of others' actions —the results. In addition, when observing the combination of actions and their results, infants may begin to understand why people behave the way they do—their goals. Particularly useful situations in this regard would include instances in which the demonstrator did not succeed the first time or performed the same action on several occasions, with irrelevant or accidental actions accompanying the intentional action sometimes. Of course, the path of development is not unidirectional: once infants understand others' goals, for example, they can make better sense of their actions (see, e.g., Bekkering, Wohlschläger, and Gattis 2000).

The implications of this account are far reaching because it points to attending to and copying actions as one of the most important components in the cognitive and social development of children. Although using imitation as a key component is not a new idea (Piaget 1962; Meltzoff and Gopnik 1993; Vygotsky 1978),

our proposal is innovative for two reasons. First, it helps explain both cognitive and social-cognitive development. Through copying actions, children gain knowledge about both their physical and social worlds. Second, the account provides a comparative and a clinical perspective. In other words, it may help us to understand the differences between humans and apes on the one hand, and between typically developing children and children with autism on the other.

APES

We have distinguished three types of information that can be attended to by observers. Moreover, we have argued that humans are capable of focusing on each of these sources independently, depending on the demands of the situation. One important question is whether other animals can also extract all three different types of information. Of particular interest is whether the great apes are capable of benefiting from all sources of information.

Current evidence on social learning in apes indicates that chimpanzees and orangutans seem to rely primarily on results as their main source of information in problem-solving situations (Call and Tomasello 1994a, 1995; Myowa-Yamakoshi and Matsuzawa 1999; Nagell, Olguin, and Tomasello 1993). These studies indicate that apes are more likely to reproduce results (changes in the environment) than the demonstrator's actions. In fact, evidence of apes copying the actions of a demonstrator independently from its results in a problem solving situation is relatively scarce (but see Whiten et al. 1996). Copying actions from demonstrators is better characterized as a fragile phenomenon at best, one that may be difficult to elicit systematically. Even studies that have specifically trained subjects to reproduce actions on command have met with limited success. For instance, Custance, Whiten, and Bard (1995) found that two juvenile nursery-reared chimpanzees copied less than a third of a set of novel actions after several weeks of training. This study shows that copying actions is not something that chimpanzees do easily or often. Perhaps the apes in this study were attending to other things, like results or goals. To tease apart these different possibilities, other studies along the lines of those by Bekkering, Wohlschläger, and Gattis (2000), Carpenter, Akhtar, and Tomasello (1998), and Meltzoff (1995) are needed.

At present, the general characterization that we favor is one that depicts apes as being biased toward copying results and only rarely copying the actions that bring about those results. In other

words, apes may preferentially attend to the changes in the environment rather than to the actions that bring about those changes. This is not to say that apes are incapable of attending to or encoding information about the demonstrator's actions (see Myowa-Yamakoshi 2001, for a discussion) under any circumstances, it is simply that during their normal ontogeny they tend to preferentially focus their attention on results rather than actions.

Interestingly, apes that have been enculturated—that is, raised by humans in the same way as human children—seem to be more adept at copying actions in addition to copying results. Tomasello, Savage-Rumbaugh, and Kruger (1993; see also Hayes and Hayes 1952) found that enculturated bonobos and chimpanzees reproduced a human demonstrator's actions in an object-manipulation task more often than mother-raised apes. The percentage of reproduced actions by enculturated apes in that study was comparable to that of $2\frac{1}{2}$-year-old children presented with the same models and objects. The case for an enhanced ability to focus on actions in enculturated apes is further reinforced by other studies that have shown that enculturated apes outperform mother-reared apes in other domains such as gestural communication (Call and Tomasello 1994b, 1996; Gómez 1996), gaze following (Call, Agnetta, and Tomasello 2000; Itakura and Tanaka 1998), distinguishing accidental from intentional actions (Call and Tomasello 1998), and language acquisition (Savage-Rumbaugh et al. 1986). What all these studies have in common is that they require subjects to focus their attention on the actions performed by humans. At this point, we can only speculate that it is the type of social engagement that apes encounter in their human foster homes that promotes their ability to focus on human actions, not just the results of those actions. In particular, the socialization of attention—that is, the guiding of attention to particular features in the environment—may play a fundamental role in the ability to shift attention from results to actions and vice versa. These suggestive findings may highlight the importance of ontogeny in the development of attention to the various sources of information that emanate from a model and which are the basis for the various social learning mechanisms that we have explored.

INDIVIDUALS WITH AUTISM

Special human populations with developmental delays also constitute an interesting case to study. Particularly interesting is the case of people with autism. Children with autism show some

impairment in their imitative skills (see Rogers 1999; Smith and Bryson 1994 for reviews), although there have been very few studies of imitation in individuals with autism that have addressed the kinds of questions we are concerned with here. Perhaps the most interesting is a recent study by Hobson and Lee (1999). In this study, participants watched as a demonstrator modeled several actions on objects. During each model, the demonstrator performed the action in a particular way—with a particular "style" (e.g., gently or forcefully). Hobson and Lee found that whereas participants reproduced the results of the actions equally as well as control participants with developmental delays but not autism, the participants with autism were less likely than the control participants to reproduce the style the demonstrator used to bring about those results. These findings suggest that individuals with autism may be biased toward attending to and reproducing results rather than actions.

If indeed children with autism (and apes) preferentially pay attention to the results of others' actions instead of the actions themselves, then, following our account of typical development, individuals in these two populations may be missing out on an important way of learning about the social world. That is, whereas the information they gain from focusing on the results of demonstrations may help them learn about the physical world, the information they miss out on by not focusing on actions may hinder their development of an understanding of other individuals. This may help explain the specific pattern of relatively intact physical cognition and relatively impaired social cognition (e.g., skills related to theory of mind) of children with autism and apes, at least as compared with typically developing human children. Of course we realize that the reverse situation could be true too—that an early lack of understanding of or interest in other individuals could account for the tendency to pay attention to results over actions. That is, depending on one's theoretical orientation, these differences in focus on results over actions may be either a cause (e.g., Meltzoff and Gopnik 1993; Rogers and Pennington 1991) or an effect (e.g., Tomasello, Kruger, and Ratner 1993) of difficulties with normal human social-cognitive understanding.

9.4 Conclusion

In this chapter, we propose a new way of looking at social learning: a multidimensional framework that considers each source of

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information available in a model—goals, actions, and results—separately and in relation to each other. We believe that this framework is more useful than using only the terms already available because it helps us interpret individual instances of social learning and explain new results with more precision. We also think that this framework may be useful theoretically in comparative and clinical perspectives and we hope that it will stimulate research into the different sources of information in a variety of populations.

A final caveat: when considering the different sources of information simultaneously, an effort should be made not to favor one source over the others, or to view the use of one of the sources as more cognitively sophisticated than the others. This situation tends to occur when scholars with different theoretical orientations such as behaviorists and cognitivists tackle the question from different ends of the spectrum. However, it is important to emphasize that attributing a higher cognitive complexity to the use of one or the other source of information is not very useful because the three sources belong to different cognitive dimensions. Whereas understanding goals is sophisticated because it may inform us about what subjects know about others' minds, reproducing results is complex because it entails extracting pieces of information and putting them together to create a novel solution (Call 1999). Each of these two sources is at opposite ends of the spectrum: inferring goals belongs to the domain of social cognition, whereas piecing together results to solve a problem belongs to the domain of physical cognition. Finally, copying actions is in between goals and results because this has both physical and social attributes. On the one hand, it is social because it entails paying attention to social entities, but at the same time, it is closely related to motor and cross-modal skills since visual information must be transformed into kinesthetic information.

Imitation is usually taken to be more complex than emulation. We think this is problematic and we present the following scenario to illustrate this point. Researchers in the field of robotics (e.g., Breazeal and Scassellati, chapter 14 of this volume; Demiris and Hayes, chapter 13 of this volume) are currently working very hard to create robots that can copy others' actions. This is an admirable and useful objective and we are impressed with the results to date (see other chapters in this volume). However, imagine how impressive it would be to create a robot that could *emulate*—that is, observe the achieved change of state in the environment and come

up with its own way of reproducing that change of state. We presume that this would be a more serious challenge to programmers than making a robot that uncreatively mimics others' actions. We therefore propose a more egalitarian approach to the study of social learning, with goals, actions, and results—and imitation, emulation, and the other social learning mechanisms—considered equally important and deserving of study.

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Note

1. For instance, in the Easter egg example from figure 9.1, an individual may understand that the goal of a demonstration is to open the egg to get the prize inside. But he may copy the actions and reproduce the results of the demonstrator to achieve a different goal: using half of the egg as a cup to scoop up water.

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10 The Mirror Syst

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10.1 Introduction

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