“Stop copying me!” shrieks a friend’s seven-year-old as she admires her bead-bedecked image in the mirror. “I not copying!” responds her three-year-old sister indignantly, while fingering rows of beaded necklaces around her own neck. Anyone who has observed a similar scene knows that a heated argument follows about “what counts” as copying, and whether playing with beads might be the result of the beckoning sparkle of beads or the desire to do whatever an older sibling does. What counts as copying, and similarly what counts as imitation, depends not only on arbitrary boundaries drawn by scientists and three-year-olds, but on the motivations and mechanisms involved. At least four mechanisms have been proposed to explain behaviors performed after seeing them performed by another animal. The likelihood of some behaviors is increased by stimulus enhancement when an object is manipulated by an animal subsequent to being handled or moved by another animal (Thorpe, 1956). The object itself is considered to trigger the behavior, perhaps through perceptual affordances, and the behavior of the first animal merely highlights the object, rather than providing an action model. Alternatively, some behaviors may be initiated by the observation of an action model, which triggers a specific and preorganized action pattern. Such innate releasing mechanisms (Lorenz & Tinbergen, 1938, as cited in Meltzoff & Moore, 1983) may explain exact copying of surprisingly complex behaviors observed in many nonhuman animals. Direct mapping between perceptual and motor neurons or brain systems, observed in both monkeys and humans (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995; Pellegrino et al., 1992), has been proposed as a more sophisticated mechanism accounting for other copying behaviors, including neonate imitation of facial gestures (Meltzoff & Moore, 1983). None of these three mechanisms explains why “what counts” as imitation for most of us is rarely observed in the animal kingdom. Acquiring complex and skillful behaviors by observation, most researchers seem to agree, is a human-specific or primate-specific trait.
Why is imitation so rare? Recent work from developmental psychology, primatology, and motor learning seems to coalesce in a single proposal: some behaviors are generated from a goal-sensitive mapping between observed actions and performed actions. Observed behaviors are decomposed into constituent parts and recomposed as an action pattern, according to the perceived or inferred goals of the behavior. The purpose of this chapter is to review research concerning this fourth mechanism, goal-directed imitation.

Perceiving and inferring goals in imitation

Two sets of findings suggest that at least some forms of imitative behavior involve goals. First, enabling sequences of events are imitated more accurately than arbitrary sequences of events. Developmental psychologists using an elicited imitation paradigm to study event memory in very young children modeled action sequences for sixteen- to 24-month-old children and then encouraged the children to imitate the modeled actions (Bauer & Mandler, 1989; Bauer & Shore, 1987; Bauer & Travis, 1993). Novel-arbitrary sequences involved novel actions with simple objects, such as putting a sticker on a chalkboard, leaning the board against an easel, and drawing on the board with chalk. Novel-enabling sequences also involved novel actions with objects, with the difference that actions in a novel-enabling sequence enabled other actions in the sequence, and ultimately led to a salient novel event, such as a toy frog “jumping” in the air. The frog-jump sequence, for example, involved putting a wooden board on a wedge-shaped block to form a lever, placing a toy frog on one end of the board, and hitting the other end of the board, causing the toy frog to appear to jump in the air. Children of all ages performed the modeled actions in the modeled order more frequently for novel-enabling sequences than novel-arbitrary sequences. This result provides some evidence that the presence of an unambiguous, observable outcome leads to more accurate imitative behavior in young children. As Bauer (1992) has noted, however, enabling sequences must be performed in a particular order, whereas arbitrary sequences by definition do not impose this requirement.

Further research has demonstrated that an enabling sequence with a salient outcome is imitated more frequently than an enabling sequence without a salient outcome, and furthermore that the sequences themselves are reorganized by children during imitation. Travis (1997) demonstrated interleaved pairs of three-step action sequences to 24-month-old children. Children were shown either six actions (three actions for each pair), or only five actions, with the end-state for one sequence
omitted. When shown two-end-state pairs, children imitated both action sequences equally. In contrast, when shown one-end-state pairs, children imitated more actions from the end-state-present sequence than from the end-state-absent sequence. Most important for our discussion here, however, is that children in both conditions performed actions leading to a particular end-state as a temporally contiguous sequence—despite the fact that end-state-related actions were not temporally contiguous in the modeled sequence, since they were interleaved with actions from another sequence. This temporal reorganization of actions during the imitation phase suggests that not only do goals motivate imitation, but they also play an important organizational role in imitative behavior.

We want to distinguish here between two senses in which the term “goal” has been used in describing imitative behavior. The end-states used by Bauer, Travis, and colleagues were salient outcomes involving movement, noise, or both. Many researchers have referred to salient outcomes as the goals of imitative acts (Byrne & Russon, 1998; Travis, 1997; Whiten & Ham, 1992), and appropriately so in that it is simple for an observer to conclude that the goal of the frog sequence is to make the frog jump. Strictly defined, however, a goal is “a mental state representing a desired state of affairs in the world” (Travis, 1997: 115), and is therefore not observable. Because goals are not observable, identifying the unobservable goal of an observable action always requires an inference. That inference is sometimes easy and sometimes difficult. Actions with highly salient outcomes simplify the task of inferring the mental states of others, and increase the likelihood that the goal inferred by an observer will be similar to the goal of the actor. Some behaviors have less salient or less observable consequences, however, or involve multiple goals, and can nonetheless be imitated, as for example when learning to dance the tango, to write an efficient computer program, to make new friends, or to cope with failure. An understanding of goal-directed imitation therefore is likely to benefit from an investigation of goals as mental and not merely physical states, and it is this aspect of goals to which we wish to direct attention in this chapter.

 Appropriately then, the second set of experiments suggesting that goals play an important role in imitative behavior comes from developmental psychologists interested in children’s understanding of the intentions of others (Carpenter, Akhtar, & Tomasello, 1998; Meltzoff, 1995). These experiments demonstrate that even very young children are capable of inferring goals from observed actions, and that inferred goals influence imitative behavior. Meltzoff (1995) compared eighteen-month-old children’s re-enactments of an attempted but failed action, or an attempted and achieved action with five unique test objects. For example, an adult
experimenter moved a rectangular wooden stick toward a rectangular recessed button on a box, and either inserted the stick in the hole, activating a buzzer, or touched an adjacent area on the box, missing the hole and not activating the buzzer. When given the opportunity to manipulate the objects immediately after the adult’s demonstration, children shown an attempted but failed act were just as likely to perform the target act, for example inserting the stick in the hole and activating the buzzer, as children shown an attempted and achieved act. This result is especially surprising because children shown a failed attempt never actually saw the target act performed. Children in both groups performed the target act approximately four times as often as did children in control conditions. The finding that eighteen-month-olds imitated intended acts just as often as achieved acts suggests that even very young children infer the goals of others’ behaviors, and imitate those inferred goals.

In a similar paradigm, Carpenter, Akhtar, and Tomasello (1998) compared fourteen- to eighteen-month-old children’s reenactments of verbally marked intentional and nonintentional acts. An experimenter performed two unrelated actions on a unique test object, for instance lifting the top of a bird feeder, and pulling a ring on a string attached to the feeder. These actions were accompanied by vocal exclamations marking each action as either an intended act (“There!”) or an accidental act (“Woops!”). After both actions had been performed (with some children seeing first an intentional and then an accidental act, and others seeing the opposite order), a salient event occurred, for instance a party favor attached to the bird feeder moved and made noise. Following two actions and the salient event, the experimenter offered the infant an opportunity, saying “Now you try. Can you make it work?” Irrespective of the order of the modeled actions, children reproduced the intentional acts approximately twice as often as nonintentional acts. Together these two sets of results suggest that when observing an adult’s behavior, a child relies on observable information such as direction of movement and verbal exclamations to draw inferences about the nonobservable intentions of the adult, and that these inferences about goals or intentions influence subsequent imitative behavior.

Distinguishing goals from outcomes

The distinction between goals as outcomes and goals as mental states turns out to be crucial for understanding current debates about what counts as imitation and whether nonhuman primates do or do not imitate. Several investigations of imitative behavior in nonhuman primates suggest that while primates may reproduce the outcome of an observed
event, the strategies employed in reproduction of that event do not reliably correspond to the actor’s strategies. For example, Nagell, Olguin, and Tomasello (1993) reported two studies in which chimpanzees and 23- to 25-month-old children observed a human demonstrator use a tool resembling a rake to retrieve an out-of-reach reward (food or a toy, for chimpanzees and children respectively). The demonstrator began with a rake in one of two positions, either with the teeth down or with the crossbar down. When the rake began in a teeth-down position, the experimenter flipped the rake so that the cross bar was down, and then used the crossbar of the rake to drag the object within reach. When the rake began in a crossbar-down position, the experimenter simply dragged the object within reach, again using the crossbar of the rake. A similar rake was provided for human and chimpanzee observers, always resting in a teeth-down position. The question of interest was not simply whether children and chimpanzees used the rake to obtain the reward, but how they used it, and whether that use was influenced by the demonstrator’s behavior. Children who observed the demonstrator flipping the rake to an edge-down position before beginning to pull were more likely to do the same and to use the edge-down rake to drag the object within reach compared to children who did not observe the flipping action. Children who observed the demonstrator pulling but not flipping used the rake in the found, teeth-down, position, and simply pulled. In contrast, chimpanzees flipped and pulled or pulled only with equal likelihood in both observer conditions. In other words, while both children and chimpanzees learned by observation to use the rake to obtain the reward, the demonstrator’s behavior influenced the behavioral strategy employed by children but not the behavioral strategy employed by chimpanzees. Nagell, Olguin, and Tomasello (1993) concluded that chimpanzees attended to the end result of the task (obtaining a reward) and to the functional relations involved in the task (obtaining the reward using the rake) but failed to adopt the strategy used by the human model. Tomasello and colleagues name such behavior emulation learning (Tomasello, 1990, 1996; Tomasello & Call, 1997).

Most scientists seem to agree that the behaviors Tomasello and colleagues call emulation, such as the behaviors of chimpanzees above, do not count as imitation. Disagreement exists, however, about how to cognitively describe what animals are doing when they are emulating and notimitating. Several researchers have described emulation learning as the reproduction of goals to the exclusion of strategies, renaming the phenomenon goal emulation (Byrne & Russon, 1998; Whiten & Ham, 1992). The lesson learned from the results reported by Nagell, Olguin, and Tomasello and other similar studies (e.g., Call & Tomasello, 1995),
however, is that while observable physical outcomes are frequently copied by nonhuman primates, goals are not (see Tomasello, 1998). The tendency of nonhuman primates to reproduce outcomes previously produced by a model has thus made the empirical distinction between imitation and emulation and other nonimitative actions difficult. This distinction has been further obscured by the use in empirical studies of enabling event sequences or sequences that involve observable functional relations.

One approach to clarifying the debate has been to use more elaborate event sequences (for instance, those described by Byrne & Russon, 1998; Call & Tomasello, 1995; Whiten, 1998). For the most part these elaborate event sequences involve multiple physical outcomes and/or multiple functional relations, all of which are observable (and in fact, whether researchers conclude that nonhuman primates are capable of imitation or not corresponds to whether the functional relations and outcomes used in their experiments are observable or not). It is important to note that such event sequences allow researchers to investigate whether nonhuman primates are capable of structuring multiple actions or outcomes during imitation, but not whether nonhuman primates infer the goals of others’ actions, and whether those inferred goals then guide imitative behavior.

Both the numerosity and the unobservability of goals are characteristic of human behavior, and make life in a human colony interesting. Whenever two humans interact, each may expend considerable energy drawing inferences about the unspoken intentions of the other, and in most cases neither will know whether those inferences were correct. Such ambiguity is the very reason why many researchers of imitation have empirically defined goals as observable events, rather than mental states. In several recent studies (Bekkering, Wohlschlager, & Gattis, 2000; Wohlschlager, Gattis, & Bekkering, 2001), we chose instead to capitalize upon the ambiguity and multiplicity of goals as mental states. We used a task in which observable behaviors led to different imitative actions depending upon the goals inferred by observers, and their capacity to coordinate those goals.

Goal-directed gestural imitation

The hand-to-ear task

Whereas ethologists, comparative psychologists, and developmental psychologists have for the most part studied imitative learning of ecologically motivated behaviors, neurologists have often studied imitation of seemingly arbitrary behaviors such as gestures (for many examples, see
Berges & Lezine, 1965, and Goldenberg & Hermsdörfer, this volume). In one frequently studied gesture set, a model touches each ear with each hand, for a total of four different gestures, and asks an observer to copy each of the gestures. For these four gestures (and other similar hand-to-body-part gestures), researchers have observed a consistent error pattern in young children and aphasic adults: contralateral gestures, such as touching the right ear with the left hand, are imitated with ipsilateral gestures, such as touching the right ear with the right hand (Gordon, 1922; Head, 1920; Schofield, 1976a, 1976b). In cases of normal development, this pattern is strongest at about four years of age, decreases between ages four and six, and disappears by about age ten (Schofield, 1976b). The substitution of ipsilateral for contralateral movements during imitation has been attributed to brain lateralization and related difficulties of moving in contralateral hemispace. Developmental changes in the corpus callosum corresponding to the developmental decrease in substitution errors support this view (Salamy, 1976).

Schofield (1976a, 1976b) demonstrated, however, that substitution errors are not symmetric. In his experiments, contralateral movements were most frequent when the response involved a child’s preferred hand, and least frequent when the response involved the nonpreferred hand. Schofield questioned whether immature callosal development could explain difficulties in crossing the body midline in one direction but not the other, and suggested that young children may not find contralateral movements more difficult than ipsilateral movements, but simply do not understand what is required in this particular imitation task.

To rephrase and elaborate on Schofield’s explanation, children seemed to be having difficulty inferring or processing the goals of the imitative task.

With this in mind, we used similar ipsilateral and contralateral gestures to investigate how inferring and processing goals influences imitative behavior in preschool-age children. Because this phenomenon had been previously demonstrated in three- to six-year-old children, we conducted these experiments with preschool children ranging from three to six years, with an average age of 4.5 years. Age was not used as a factor in the analyses described below.

In the first of these experiments, a model demonstrated six hand-to-ear movements and asked the children to mirror the movements (Bekkering, Wohlschläger, & Gattis, 2000). The six movements were the four gestures described above, plus two additional gestures: grasping both ears with both hands ipsilaterally (so that the arms are parallel) and grasping both ears with both hands contralaterally (so that the arms cross). We added the latter two movements to the gesture set to test the lateralization
hypothesis against a goal-directed view. We reasoned that if substitution errors were due to immature callosal development, young children would make just as many substitution errors in imitating bimanual contralateral movements as in imitating unimanual contralateral movements. If, however, substitution errors were due to difficulties in inferring or processing the goals of the imitative task, the salience of crossed arms in the bimanual contralateral condition should result in fewer substitution errors compared to unimanual contralateral conditions. We expected that the salient feature of crossed arms could be encoded as a goal of the observed behavior, and therefore boost performance in the bimanual contralateral condition, relative to the unimanual contralateral condition. The results indicated that substitution errors cannot be due to immature callosal development alone. When imitating single-handed gestures, children accurately imitated ipsilateral gestures (see Fig. 10.1) but not contralateral gestures (see Fig. 10.2), substituting an ipsilateral movement for the modeled contralateral movement on 48 per cent of the trials. Significantly, however, this substitution error was dramatically decreased when the hand-to-ear movements involved both hands: children substituted an ipsilateral gesture for a contralateral gesture on only 10 per cent of bimanual trials (see Fig. 10.3).
Goal-directed imitation

To account for these results, we proposed that imitation entails representing an observed behavior as a set of goals, which subsequently drive the construction of an action pattern (Bekkering, Wohlschlager, & Gattis, 2000). Goals may represent the objects at which actions are directed (for instance, a particular ear), the agents that perform actions (a particular hand), movement paths (crossing the body or moving parallel to the body) or other salient features (crossing the arms). We also proposed that imitative goals are organized hierarchically with some goals dominating over others. When processing capacity is limited and multiple goals compete for capacity, goals higher in the hierarchy are reproduced at the expense of goals lower in the hierarchy. Because young children have difficulty processing multiple elements and relations, their failures to reproduce all the goals of a movement are more noticeable. Our results suggested that objects occupy the top of the goal hierarchy—children nearly always grasped the correct ear, but in cases of substitution errors used the wrong hand and the wrong movement path. This view of imitation predicts that children’s imitation errors are malleable, and dependent on the number and type of goals identified in the task as a whole.

Figure 10.2. The contralateral substitution error occurred when the experimenter modeled a contralateral gesture, and children responded with an ipsilateral gesture.

The goal-directed view
Figure 10.3. When the experimenter modeled a contralateral gesture involving both hands, children appropriately responded with a bimanual contralateral gesture.

Testing the goal-directed view

We tested this prediction in several additional experiments by reducing or increasing the number of goals identifiable in the imitative task as a whole. All of these experiments involved the same basic idea of a set of ipsilateral and contralateral gestures, and all involved the two gestures we were most interested in comparing: a unimanual ipsilateral gesture, and a unimanual contralateral gesture. What varied between the experiments is the context in which those two gestures occurred.

In one experiment, we limited the movements to only one ear, thereby eliminating the necessity for children to mentally specify the goal object (Bekkering, Wohlschläger, & Gattis, 2000). Children copied the movements of a model who always touched her right ear (first with one hand and then the other), or who always touched her left ear (again alternating hands). In this circumstance, children made virtually no errors, grasping the ear contralaterally whenever the model did so. Eliminating the necessity of specifying a particular ear as goal object thus enabled children to reproduce other goals in the imitative act, such as using the correct hand and the correct movement path.

In another experiment, we manipulated the number of identifiable goals by comparing the presence and absence of objects while keeping
the total number of modeled gestures constant (Bekkering, Wohlschläger, & Gattis, 2000). Children sat at a desk across from the experimenter, who made four unimanual gestures similar to those described above, but directed at the desk rather than at her ears. Half of the children saw four dots on the table, two in front of the model and two in front of the child. The model touched her dots ipsilaterally and contralaterally, sometimes with her right hand and sometimes with her left hand. Children were encouraged to copy the model, and naturally directed their own actions at the two corresponding dots in front of them. For the other half of the children, the model directed her actions at the same locations on the table, with the crucial difference that no dots were on the table. Children in the dot condition produced the classic error pattern, substituting ipsilateral for contralateral gestures (see Fig. 10.4). In contrast, children

Figure 10.4. Children shown gestures directed at dots on a table produced the classic error pattern, substituting ipsilateral for contralateral
in the no-dot condition who saw the identical movements directed at locations rather than dots produced significantly fewer contralateral errors (see Fig. 10.5). We concluded that manipulating the presence or absence of a physical object had effectively manipulated the necessity of specifying objects as goals. Despite the fact that the modeled movements were identical in both conditions, removing the dots from the table eliminated the object goal, and allowed children to reproduce other goals in the imitative act, such as the agent and the movement.

A third experiment attempted to reduce goal competition by segmenting the imitative task into two phases (Wohlschläger, Gattis, & Bekkering, 2001). In the first phase, the experimenter extended a hand, and waited...
for the child to extend a hand. Once the child had done so, the experimenter initiated the second phase by raising her extended hand to touch either the ipsilateral or contralateral ear. This two-phase procedure was used for all four unimanual gestures – touching the right ear with the right hand, the left ear with the left hand, the right ear with the left hand, and the left ear with the right hand. We reasoned that if goal competition causes imitative errors, segmenting the task into two phases, in which first a particular hand was chosen, and then a particular ear was chosen, would reduce competition and thereby reduce imitative errors. In this two-phase task, the substitution of contralateral for ipsilateral hand movements virtually vanished, once again supporting the claim that goal competition causes imitative errors. We should also note however, that somewhat contrary to our predictions, some unimanual contralateral movements were imitated with an unusual bimanual movement in which a child extended the left hand, and then touched the right ear with the right hand. This error can be interpreted as a subtle persistence of the substitution error, or perhaps as unexpected cleverness on the part of four-year-olds.

In a fourth experiment, we again tested the prediction that children’s imitation errors are caused by competing goals but this time we did so by increasing, rather than reducing, the number of goals in the imitative task (Wohlschlager, Gattis, & Bekkering, 2001). For all trials of this experiment, the experimenter reached to the location in space near her left or right ear, using the left or right hand, so that once again half of the gestures were ipsilateral and half of the gestures were contralateral. Rather than touching her ear, however, the experimenter moved her hand to the space next to her ear, and either made a fist, or opened her hand, with the palm facing the child. We reasoned that the open-hand versus closed-hand introduced a new, salient gestural goal, and wanted to know whether a specific hand gesture, like the object goal, would displace other goals such as agents and movements. This was indeed the case. Children reproduced the open-hand or closed-hand of the experimenter nearly all the time, but frequently substituted a different hand (Fig. 10.6), and sometimes even performed the gesture on a different side of the head (Fig. 10.7). This result indicates that increasing the number of goals in the imitative task increases the number and type of imitative errors. More specifically, it also suggests that a specific hand gesture, much like objects, may take precedence in the goal hierarchy guiding imitative behavior.

Using a similar paradigm to the one described above, Gleissner, Meltzoff, and Bekkering (2000) manipulated whether gestures were directed at locations on the body, or locations near the body. A model performed ipsilateral and contralateral movements with her right or left hand or with both hands. The model either touched a body part (an ear
or a knee), or directed her movement at a location in space near the body part. In general, three-year-olds imitated more accurately when the model’s actions were directed at locations near the body, than when her actions were directed at locations on the body. Error differences between the two conditions were generalized, however, and the classic substitution error was not significantly reduced in the near-a-body-part condition compared to the on-a-body-part condition (see Gleissner, 1998, for details). This result thus lends tentative support to the proposal that imitation is organized around goals, and that objects (such as an ear or a knee) tend to displace other goals in the imitative act, such as hand and movement path.

**Testing alternative hypotheses**

Several additional experiments investigated the hypothesis that children’s difficulties in gestural imitation might be due to other cognitive constraints, such as limitations on perception or attention, rather