FOURTEEN- THROUGH 18-MONTH-OLD INFANTS DIFFERENTIALLY IMITATE INTENTIONAL AND ACCIDENTAL ACTIONS

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This study explored infants’ ability to discriminate between, and their tendency to reproduce, the accidental and intentional actions of others. Twenty 14- through 18-month-olds watched an adult perform a series of two-step actions on objects that made interesting results occur. Some of the modeled actions were marked vocally as intentional (“There!”), some were marked vocally as accidental (“Woops!”). Following each demonstration, infants were given a chance to make the result occur themselves. Overall, infants imitated almost twice as many of the adult’s intentional actions as her accidental ones. Infants before age 18 months thus may understand something about the intentions of other persons. This understanding represents infants’ first step toward adult-like social cognition and underlies their acquisition of language and other cultural skills.

Understanding others’ intentions is one of infants’ first steps toward a theory of mind, that is, an understanding that other people have mental states such as desires, knowledge, and beliefs. Older children clearly understand a great deal about others’ intentions. When 5- to 6-year-old children make moral judgments, they take into account the intentions of the people involved: even when unintended actions result in the same amount of damage as...
intended actions, they are viewed as less “naughty” (e.g., Karniol, 1978). In addition, children as young as 3 years of age have been found to be able to distinguish intentional actions from mistakes, reflexes, and passive movements (Shultz, Wells, Sarda; 1980; see also Shultz & Wells, 1985; Smith, 1978).

Whereas studies of older children’s understanding of others’ intentions involve explicit, linguistic explanations of behavior, studies of this understanding in children 2 years old and younger must involve more implicit measures. Several studies of young infants have used measures of habituation-dishabituation (e.g., Gergely, Csibra, Biró, & Koós, 1994; Gergely, Nádasdy, Csibra, & Biró, 1995) or gaze direction (Phillips, Baron-Cohen, & Rutter, 1992). These studies have found that by 9 months of age, infants are sensitive to rational, goal-directed action, and that they engage in “goal detection” following ambiguous actions by looking to the actor’s face. Because such studies rely solely on infants’ patterns of gaze, many studies of very young children’s understanding of intentions use imitation paradigms.

There are several types of social learning by means of which one individual may end up reproducing the actions of another individual (see Galef, 1988; Whiten & Ham, 1992). Tomasello (1996; Tomasello, Kruger, Ratner, 1993) has singled out imitative learning as the only type of social learning that involves some understanding of the intentions behind others’ actions. That is, the process of mimicking, as in parrots mimicking human speech, involves reproducing the means only, or topography of others’ motor activities without an understanding of their goal or intention. Conversely, processes such as local enhancement or emulation learning involve reproducing the end only, or the change of state in the world produced by others, but doing so without any regard for their actual behavior or behavioral strategies. Imitative learning consists of reproducing the intentional actions of others, including both the end result or goal at which they are aiming and the behavior or strategy by means of which they are attempting to accomplish that goal (Tomasello, 1996).

Infants as young as 6 months of age can reproduce others’ actions on objects (e.g., Barr, Dowden, & Hayne, 1996). However, it is not until age 13 or 14 months that there is evidence of imitative learning. In a study by Meltzoff (1988), 14-month-old infants watched, along with other demonstrations, an adult bend at the waist and touch a panel with his forehead, thus turning on a light. The infants followed suit even though they might also have turned on the light by simpler means (e.g., with their hands)—implying that they were indeed reproducing the adult’s behavioral act. To test the possibility that infants at this age were only mimicking the adult, that is, reproducing the adult’s action without also trying to achieve the same goal as the adult, Carpenter, Nagell, and Tomasello (in press) included similar actions in a longitudinal study of 24 infants from 9 to 15 months of age. Results showed that at an average age of 13 months infants began not only to reproduce an adult’s “arbitrary” action to achieve an effect—for example, knocking on or touching their head to a plain wooden box to activate a light—but they also accompanied their behavioral reproductions with a look to the light, in apparent anticipation that their behavioral act would produce the same effect as had the adult’s. Bauer and Hertsgaard (1993) also have shown that 13.5-month-olds can reproduce novel sequences of two or three actions on objects in order to meet a goal (in that study, the goal of the actions was verbally stated by the experimenter during the demonstration and response periods).

In perhaps the most direct test of infants’ understanding of others’ intentions, Meltzoff (1995) showed 18-month-old infants an adult trying but failing to perform several actions on objects. When given an opportunity to play with the objects themselves, the infants reproduced what the adult was trying but failing to do, an action they had never seen in its entirety. They did this more often than infants in various other control conditions (and as
often as infants who saw successful performance of the act).

Tomasello and colleagues also have used imitative learning paradigms to investigate 18- to 24-month-olds’ understanding of others’ intentions, although in these studies what is imitated is a piece of language instead of actions on objects. Tomasello, Strosberg, and Akhtar (1996) reported a study of 18-month-old infants in which an adult used a novel word in announcing her intention to “find the toma.” Infants then watched as the adult searched a series of buckets for the toma, picking up and rejecting objects on the way (scowling and replacing them) before picking up another object with obvious glee. Children learned (i.e., imitated) the word “toma” for the object reacted to with glee (and not for the rejected objects), presumably indicating their ability both to understand that the adult’s goal was to find the toma and to tell when she had fulfilled that goal.

What is perhaps a more stringent test of young children’s ability to understand intentional actions was employed by Tomasello and Barton (1994) with 24-month-old children. In this study, an adult announced to 24-month-olds her intention to produce an action (“Let’s meek Big Bird”) and proceeded to an apparatus where two novel actions were possible. In one condition she first produced an accidental action (saying “Woops!”) followed by an intentional action (saying “There!”), with appropriate vocal intonations in both cases. In another condition the order of accidental and intentional actions was reversed (and there was counterbalancing of actions and conditions). In both conditions children learned the new word to refer to the intentional action (i.e., irrespective of the order in which the two actions were performed), indicating both their ability to discriminate intentional from accidental actions and their tendency to reproduce intentional actions. This discrimination is different from the one required in the experimental paradigms in which infants only had to see certain behaviors or emotional reactions as indicative of a certain intentional action in a certain context (as in the Meltzoff, 1995, and Tomasello et al., 1996, studies). In this study, two actions were performed before the child had an opportunity to act, and the child then had to choose which one (or both) the adult intended to perform—using an entirely different set of cues than in the other studies of infants’ understanding of intentional action. This is arguably a more difficult task.

Studies of infants’ understanding of accidental and unfulfilled intentions are particularly important when assessing infants’ understanding of others’ intentions, because they involve the understanding that others may have intentions that may not match with the current state of affairs. This advanced level of understanding may be contrasted with simply understanding persons in terms of their intentions and understanding that others may have intentions that differ from one’s own (Tomasello, 1995); the latter two, earlier levels of understanding may be seen in infants as young as 9 to 12 months of age (see Tomasello, 1995 for further discussion). Indeed, studies of accidental and unfulfilled intentions are analogous to studies of false belief, as they involve deviations from the true state of affairs, and thus may be considered an “acid test” of understanding of others’ intentions. So far, this level of understanding has been studied only in 18-month-old and older children (e.g., Meltzoff, 1995; Tomasello & Barton, 1994).

In the current study, we sought to test for this level of understanding in infants 14 through 18 months of age. In particular, we tested infants’ ability to distinguish between accidental and intentional actions, using an action imitation paradigm. Infants observed an adult demonstrate actions on objects which afforded two actions. Some infants saw an intentional action followed by an accidental action, some saw an accidental action followed by an intentional action, and some saw two intentional actions. The major discriminative cue was the adult saying “Woops!” or “There!” with the appropriate intonation as she produced a particular action. We chose vocal cues knowing that by age 12 months, infants
use adults’ vocal emotional signals more reliably than their visual-facial cues to regulate their own behavior, at least in social referencing situations (Mumme, Fernald, & Herrera, 1996). The hypothesis was that infants as young as 14 months would preferentially reproduce intentional over accidental actions in this situation—although reproduction of accidental actions might occur at some frequency as well as they would still suggest to the infants things that might be done to objects irrespective of adult intentions. Demonstration of such a preference would indicate both infants’ ability to discriminate intentional from accidental actions and their tendency to reproduce mainly the intentional actions of adults.

EXPERIMENT

Method

Participants

Twenty infants (mean age = 16 months, 6 days; range = 14 months, 1 day to 18 months, 29 days) participated in the study. Twelve of the infants were male, 8 were female; all were from middle and upper-middle class families. No infants were dropped from the study. Infants were recruited by telephone from a file of names of parents who had volunteered to participate in studies of child development. Compensation for participation included a book or a t-shirt.

Materials

Eight objects were constructed specifically for the study (two were used to warm up the infants and, if necessary, to train them—see below; the other six were used in the test). Pictures of the test objects are presented in Figure 1. Objects consisted of wooden boxes or other supports (e.g., a plastic newspaper recycler turned upside down and a wooden bird feeder), each of which had two parts or attachments that could be moved (e.g., on the top of one of the boxes, there was a hinge and a spinner; for the bird feeder, the top moved up and down and a string with a ring on it attached to the middle could be pulled). Also attached to each object was an end result (i.e., colored Christmas-tree lights, a small toy that popped out of a box and dangled on a string and then was pulled back into the box, or an air-powered party favor); end results were activated surreptitiously by an experimenter (i.e., with her hand behind a curtain, she unobtrusively switched on the lights, jigged the string attached to the small toy, or pressed repeatedly on a pump attached to the party favor). End results were activated for a few seconds after the other experimenter’s demonstrations, and after any reproductions of the target (i.e., intentional) actions by infants. A list of the objects, the actions performed on them, and their respective end results is presented in the Appendix.

In addition, at the end of the session, parents were asked to complete the short form of the MacArthur Communicative Development Inventory (Reznick & Goldsmith, 1989). This measure of infants’ vocabulary production was collected in order to determine whether there was a correlation between infants’ reproduction of intentional actions and their verbal abilities.

Experimental Design

Two actions in sequence were modeled on each of the six test objects. There were two types of actions: Accidental actions and Intentional actions. Demonstrations of Accidental actions were immediately followed by the word “Woops!” and demonstrations of Intentional actions were immediately followed by the word “There!”—both with the appropriate intonation. There were three conditions, corresponding to the order and type of actions modeled: Accidental-Intentional (A-I), Intentional-Accidental (I-A), and Intentional-Intentional (I-I). The A-I and I-A conditions served as controls for each other: if infants reproduced
only one of the two actions and they differentially reproduced the intentional action, regardless of its position in the sequence, it would indicate that they discriminated between the two types of actions and chose to imitate the intentional one. The I-I condition provided an additional test of infants’ intentional understanding. If infants could reproduce a sequence of two actions and they understood something about intentional
behavior, they should reproduce both actions only when it was appropriate to do so, that is, when both actions were modeled intentionally. Thus, if infants reproduced both actions in the I-I condition more frequently than they reproduced both actions in the A-I and I-A conditions, it would indicate that they were imitating, rather than mimicking the adult's actions. The I-I condition also served to reduce the number of consecutive accidents infants saw modeled.

Each infant participated in each condition twice (i.e., there were two A-I objects, two I-A objects, and two I-I objects for each infant). For each infant, objects were assigned to conditions randomly, and the order of presentation of objects also was random, with the stipulation that no two identical conditions would be presented consecutively. Whereas the two actions associated with a given object (e.g., for the bird feeder, lifting the top and pulling the ring) always were the same for all infants, both the order in which the actions were modeled and the condition to which they were assigned were randomized. Thus, for the bird feeder, for example, approximately half of the infants saw the top being lifted first and the ring being pulled second; the other infants saw these actions in the reverse order. In addition, some of the infants in each of these cases saw the top being moved accidentally and some of them saw it being moved intentionally.

We designed the actions to look as similar as possible when modeled as accidental or intentional, but also to be credible in both cases. Thus, the two attachments for each object were positioned such that, in the case of accidents, E1's hand could plausibly get caught on or brush against one attachment on the way to or back from the other (although with enough distance between them to reduce the likelihood that infants would themselves perform the actions truly accidentally). However, the same action (e.g., pull ring, in the case of the bird feeder) was performed in a similar manner in both the Intentional and Accidental conditions. That is, in both conditions E1 pulled the ring with her index finger in such a way that could be seen as either intentional or accidental—she did not, for example, merely brush against it in the Accidental condition and tug on it very deliberately in the Intentional condition.

In natural accidents, several bodily cues are usually available: besides the vocal cues (which include not only just a word such as “Woops!”, but also a characteristic intonation), there also may be a startled facial expression, the actor's body may jump slightly, and the actions themselves may be quicker and interrupted. In the current study, we minimized all but the vocal cues, although we did not eliminate the other cues completely. For example, during accidents, the experimenter's upper body often jumped up slightly. There also were minimal facial cues, although infants were watching the actions, not the experimenter's face, during demonstrations. The main difference between accidental and intentional actions in this study was the “Woops!” or “There!” vocalization. It was expected that vocal cues would be sufficient based on results of Mumme et al.'s (1996) social referencing study in which it was found that infants used adults' vocal emotional signals to regulate their behavior by age 12 months.

**Procedure**

Infants were seen in a Psychology Department playroom for one visit lasting approximately 30 to 45 minutes; visits were videotaped. Infants sat on the floor with a parent facing a curtain which hid the objects. Parents were instructed not to provide hints or feedback to their infants but were asked to encourage infants to approach the objects if necessary. There were two female experimenters, E1 and E2. E1 sat next to the infants, interacted with them, and modeled the actions; E2 sat to one side of the curtain, facing infants, and surreptitiously activated the objects' end results with one hand behind the curtain. She also coded infants' responses.
Training Procedure. A training phase was included for two reasons. First, this phase was used to expose infants to the objects and the general procedure of watching E1’s demonstrations to learn how to activate the objects’ end results. It was also used to provide a measure of whether individual infants were able to reproduce a sequence of two actions.

The procedure of the training phase was as follows. After a brief warm-up period, the first of the two training objects was brought out from behind the curtain and placed in front of it, facing the infant and E1. In both the training phase and the test, infants were prohibited from touching the objects until after the adult’s demonstrations. The first training object was a decorated wooden box with a silent doorbell and a large spring attached to the top; a set of colored Christmas-tree lights was the end result. For this object, E1 announced, “Watch, I’m going to show you how this works,” and then modeled a single, simple action: pressing the doorbell several times. During the training phase, E1 performed actions very deliberately (unlike during the tests) and she modeled actions without vocally marking them as accidental or intentional (i.e., without saying “woops” or “there”)—there were no accidents during this phase (but E1 did not mark the actions as intentional either). We thus were not training infants to reproduce intentional actions; we were training them to watch E1’s demonstrations to learn how to operate the objects. E2 then unobtrusively switched on the lights for several seconds, during which time E1 shared in the infant’s interest and excitement about the lights. When the lights went off, E1 encouraged the infant to take a turn, using language that did not refer to the action performed (e.g., “Now you try. Can you make it work?”). If infants reproduced the modeled action, the end result was activated for a few seconds by E2 and then E1 proceeded to the second of the two training objects. If infants did not successfully reproduce the modeled action, it was modeled again (several times, if necessary). If infants still did not reproduce the modeled action after several demonstrations, E1 taught them, using verbal and manual coaching, to perform the action (this was only rarely necessary for the first training object). Infants were then encouraged to perform the action (and receive the end result) several times before going on to the next object.

The same procedure was followed with the second of the two training objects (a different decorated wooden box), with one exception. A sequence of two actions was modeled on this object: raising and lowering a doorstop and then twanging a small spring. In order for infants to succeed on this object, they had to reproduce both of the modeled actions in the modeled order. If, as often was the case (see below), on their first attempts infants reproduced only one action (or they reproduced both in the incorrect order), E1 provided feedback until they correctly reproduced both actions or until they showed signs of frustration. During the training period, demonstrations consisted of one and two actions, respectively, so as not to bias infants toward reproducing one or both actions during the test.

Test Procedure. During the test phase, the same general procedure of E1 modeling actions and then giving infants a turn to respond was followed. During the test, however, demonstrations always consisted of two actions, and individual actions were modeled either intentionally or accidentally, depending on the condition, as discussed above. In addition, infants received only two demonstration and response trials for each test object, with no hints or training from E1. E1 modeled the first actions, gave the infant a response period, modeled the same actions again (in the same way) during a second trial, and gave the infant a second response period before moving on to the next object. Actions were performed only once per demonstration, in order to avoid repeated presentations of accidental actions. Again, following demonstrations, infants were asked, for example, “Can you make it work? Your turn,” (but never “Can you do what I did?”).
Response periods had no fixed length; if infants did not respond immediately, they were encouraged verbally and nonverbally to approach and interact with the test object until they responded in some way or until they made it clear (e.g., by walking away or fussing) that they were not going to respond. During response periods, only infants' first response was scored. If infants reproduced just one action and then paused and perhaps looked expectantly to the end result, their response was scored as one action, even if they later proceeded to perform a second action. Conversely, if infants reproduced two actions with no obvious pause in between, they were scored as having reproduced two actions. There were six objects (two in each condition), with two demonstration and response periods each, for a total of 12 trials (four in each condition).

During E1's demonstrations, the end result was activated approximately .5 to 1 sec after the second action. During infants' responses, the procedure for activating the end result differed slightly depending on the condition but always depended on whether infants reproduced the intentional action(s). In the I-I condition, the end result was activated if infants reproduced both actions in the modeled order. In the A-I condition, the end result was activated only if infants reproduced the intentional (second) action, regardless of whether or not they reproduced the accidental (first) one. In the I-A condition, the end result was activated only if infants reproduced the intentional (first) action, regardless of whether or not they reproduced the accidental (second) action, but it was done so a full 2 sec after infants performed the intentional action. This delay was implemented in order to give infants a chance to perform the accidental action.

Scoring and Reliability

Infants' responses were coded live by E2 and also from the videotapes by E1. For each trial, infants were scored as reproducing the First Action Only of the demonstration, the Second Action Only, Both Actions in Order, Both Actions in Incorrect Order, or Neither Action. If infants clearly were attempting to reproduce an action but were unsuccessful due to lack of strength or dexterity, they were given credit for reproducing that action as long as they did more than simply touch the object in the appropriate location.

E1's coding was used for analyses (E2's live coding was used when an action could not be seen clearly on the videotape). Interobserver reliability was assessed for six (30%) randomly chosen infants in the following way. Because E1's coding was not blind to experimental condition (although usually she did not watch the demonstrations), a videotape was made by an independent research assistant of only the response periods for these six infants so that the reliability coder, E2, would be blind to condition. For each response period on this videotape, E2 recorded the action(s) she saw the infant produce. Following coding, these actions were matched with the order of the actions of the corresponding demonstrations (yielding codes of First Action Only, Second Action Only, etc.) and then this blind coding was compared to E1's original coding from the videotapes. Reliability was excellent: Cohen's kappa using these coding categories was .92.

RESULTS

Following coding of infants' responses (i.e., First Action Only, Second Action Only, Both Actions in Order, Both Actions in Incorrect Order, or Neither Action), the responses were matched with the condition of the demonstration (i.e., A I, I A, or I I) and various measures of the percentages of intentional versus accidental actions reproduced were calculated (see below). Percentages were used instead of frequencies because in a few cases individual infants did not complete a total of 12 trials. Trials during which infants made no response or responded with actions other than the modeled actions were not included in analyses because we were interested not in whether infants could imitate, but, instead, in whether
when imitating they would differentiate between accidental and intentional actions. We also assumed that infants' motivational or attentional states were not ideal for these trials. The first analysis investigated infants' tendencies to reproduce intentional versus accidental actions overall, regardless of whether or not infants' responses were "correct," that is, whether or not they reproduced the intentional actions only. The second set of analyses investigated the nature of infants' responses more precisely.

The first analysis compared the overall percentage of intentional versus accidental actions reproduced by infants, regardless of whether or not infants responded correctly (that is, this analysis includes correct as well as other types of responses, i.e., responses which included accidental actions). Because no accidental actions were modeled in the I-I condition, only the A-I and I-A conditions were used for this analysis. For each infant, we counted the number of intentional actions the infant reproduced in each condition (possible range = 0-4 for each of the two conditions) and divided these numbers by the total number of intentional actions modeled in the condition (usually 4 - one intentional action in each of two trials for each of the two objects in the condition) to yield the percentage of intentional actions reproduced. Similarly, the percentages of accidental actions reproduced in each condition were calculated by dividing the number of accidental actions (range = 0-4) infants reproduced by the total number of accidental actions (usually 4) modeled. Thus, the percentage of intentional actions and the percentage of accidental actions reproduced were calculated independently and, when added together, could equal more than 100% because during any given trial infants could have reproduced both of the modeled actions.

Table 1 presents the mean percentages and standard deviations of intentional and accidental actions reproduced in each condition. A Wilcoxon signed-rank test comparing the percentage of intentional versus accidental actions reproduced in the A-I plus I-A conditions yielded significant results, \( z = 3.07, p < .01 \), with infants reproducing a significantly greater percentage of intentional actions (overall \( M = 77.7\% \) of the total intentional actions seen across these two conditions) than accidental actions (overall \( M = 42.7\% \) of the total accidental actions seen). Tests of this comparison in both the A-I and I-A conditions individually also were statistically significant, \( z = 2.26, p < .05 \) for A-I and \( z = 2.88, p < .01 \) for I-A, with no significant differences in infants' percentage of intentional or accidental actions reproduced across conditions, \( z = .79 \) for intentional actions and \( z = .73 \) for accidental actions. This finding was obtained on the level of individual infants as well: 18 of the 20 infants reproduced a greater percentage (as calculated above) of intentional than accidental actions in the A-I and I-A conditions combined, \( p < .001 \), binomial test. Infants thus imitated more of the intentional actions than the accidental ones overall.

The next set of analyses investigated infants' responses in more detail. Figure 2 presents the mean percentage of trials in which infants produced each type of response for each of the three conditions separately. To calculate these percentages, for each condition we divided the number of times infants produced each type of response (possible range = 0-4) by the total number of trials in the condition (usu-

<table>
<thead>
<tr>
<th>Condition</th>
<th>Intentional actions</th>
<th>Accidental actions</th>
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<tbody>
<tr>
<td>Accidental-Intentional (A-I)</td>
<td>74.6 (27.5)</td>
<td>45.4 (26.7)</td>
</tr>
<tr>
<td>Intentional-Accidental (I-A)</td>
<td>81.7 (20.5)</td>
<td>39.2 (33.5)</td>
</tr>
</tbody>
</table>
A-I Condition  I-A Condition  I-I Condition

Response

* This was the correct response in each case and it was significantly different from each of the other types of responses in that condition, $p < .05$.

FiguRE 2
Mean percentage of trials in which infants produced each type of response for each of the three conditions: Accidental-Intentional (A-I), Intentional-Accidental (I-A), and Intentional-Intentional (I-I).

As can be seen in Figure 2, in the A-I condition, the percentage of infants’ correct (I Only) responses ($M = 54.6\%$) was significantly greater than the percentages of each of the other (incorrect) types of responses (each of those means was less than 26\%). Wilcoxon tests, $p < .05$ in each case. Similar results were obtained in the other two conditions. In the I-A condition, the percentage of infants’ correct (I Only) responses ($M = 60.8\%$) was significantly greater than the percentages of each of the other types of responses (each of those means...
was less than 19%), \( p < .01 \) for each Wilcoxon test. In the I-I condition, the percentage of infants’ correct \( (I/I) \) responses \( (M = 41.3\%) \) was significantly greater than the percentages of each of the other types of responses (each of those means was less than 23%), \( p < .05 \) for each Wilcoxon test (see Table 2 for individual means for each type of response and \( z \) and \( p \) values for each comparison). Infants thus reproduced the correct, intentional actions significantly more often than they produced any other type of response in each of the three experimental conditions.

Of particular theoretical interest is the comparison between infants’ tendencies to engage in imitative learning versus mimicking. In the previous analysis, a correct response (reproduction of the intentional actions only) indicated imitative learning. A mimicking response was a response in which infants reproduced both actions in order in the A-I and I-A conditions, without regard for the intentionality of the actions. Recall that infants responded correctly (i.e., engaged in imitative learning) significantly more often than any other type of response, including mimicking (see Table 2 for mean percentages). Whereas in the I-I condition, imitative learning could not directly be distinguished from mimicking, a comparison of infants’ tendencies to reproduce both of the modeled actions in order in the I-I versus in the A-I and I-A conditions sheds some light on what they were doing in the I-I condition. Infants reproduced both actions in order in the I-I condition \( (M = 41.3\% \text{ of their total responses in this condition}) \) significantly more often than they did so in either the A-I \( (M = 15.8\%, \ z = 2.86, \ p < .01) \) or I-A \( (M = 11.7\%, \ z = 3.41, \ p < .001) \) conditions. Thus, infants imitated the sequence of two actions significantly more often when it was appropriate to do so, that is, when both actions were marked as intentional. They thus engaged in imitative learning more often than they mimicked throughout the experiment.

### Other Analyses

To rule out other explanations for the results presented above, a final set of analyses was conducted in which the effects of various methodological factors were investigated.

#### Practice Effects

Because infants received a total of 12 demonstration and response trials, 8 of which included accidental actions, it was important to make sure that the finding of differential imitation of intentional and accidental actions was not due solely to practice or training effects. That is, because infants were rewarded only for performing the intentional actions, they may have learned over the course of the session to discriminate and reproduce these actions for reasons other than the inten-
tionality behind them. Two sets of analyses were conducted in order to address this potential concern.

First, a comparison was made of infants’ responses on the first versus second trial for each object. The number of correct responses for each infant collapsing across all six test objects (and all three conditions) was computed for the first and second trials separately. Infants responded correctly on average 50.4% of the time following the first demonstration and 52.7% of the time following the second demonstration. This difference was not statistically significant; \( z = .45 \). A second analysis investigated whether the percentage of infants’ correct responses improved across the entire session by comparing infants’ best responses (i.e., if infants responded correctly on one of the two trials, their best response would be correct) on the first versus last object they saw. Infants’ best responses were correct 83.3% of the time for the first object, on average, and 63.2% of the time for the last (sixth) object, a finding in direct opposition to a hypothesis of practice effects. This difference was marginally significant; \( z = 1.63, p = .052 \).

Infants thus did not improve significantly either after repeated exposure to individual objects or after repeated exposure to different objects. They thus were not trained or conditioned to respond correctly but instead apparently came into the study with the ability to discriminate intentional from accidental actions. Indeed, if anything, they did more poorly at the end of the session than at the beginning. It is possible that this was due to the relatively high rate of “accidents” infants witnessed. That is, because infants saw a total of eight accidents throughout the course of their visit, their attention may have been called to these actions more than it would have been in a more natural setting and the accidental status of these actions may have decreased. If this were the case, infants might be expected to reproduce more of the accidental actions at the end of the session as compared with the beginning. This is indeed what we found: on average, infants reproduced significantly more accidental actions on the last object in the A-I or I-A condition (55.0% of the accidental actions modeled) than on the first one (35.0%). \( z = 1.90, p < .05 \).

**Blind Coding of Demonstrations.** Midway through the study, a blind coding was done of the actions to determine whether a naive adult could tell whether the action was modeled intentionally or accidentally without using E1’s vocalization. An independent research assistant watched a tape of the demonstration periods for six randomly selected infants with the sound off and made a forced choice as to whether each action was intentional or accidental. The coder, like the infants, had only one chance to watch each demonstration. The adult’s coding provided the opportunity to see whether possible visual differences in the ways accidental and intentional actions were performed affected infants’ responses. That is, if infants reproduced more of the actions that looked intentional and fewer of the actions that looked accidental, irrespective of the condition in which they were modeled, an explanation involving the saliency of the actions based on temporal or other surface features instead of intentionality would be possible.

The adult was able to guess correctly using only visual information on 75.4% of the actions (this is more than chance, binomial test, \( p < .01 \)). He incorrectly identified 26.1% of the intentional actions as accidental and 21.7% of the accidental actions as intentional. To address the issue of whether infants responded correctly based purely on visual aspects of the demonstrations, an analysis was conducted in which the correctness of infants’ responses was compared for when the blind coder was correct versus incorrect. A 2 (coder correct vs. incorrect) x 2 (infant correct—i.e., reproduced the action when it was modeled as intentional and did not reproduce it when it was modeled as accidental—vs. incorrect) chi-square analysis yielded significant results. \( \chi^2 = 6.81, p < .01 \). There was an inverse relation between the correctness of the coder and the infants, however. When the coder cor-
rectly identified the condition of the action, infants responded correctly ($M = 51.0\%$ of their responses) as often as incorrectly ($M = 49.0\%$). When the coder was incorrect, however, infants responded correctly ($M = 76.5\%$ of their responses) more often than incorrectly ($M = 23.5\%$). Infants thus responded correctly more often than not even when it was not obvious from a visual standpoint alone what type of action was being modeled. Infants’ actions thus were likely influenced more by the way in which the adult’s actions were marked vocally (“Woops!” or “There!”) than by the way they looked.

**Correlations With Age and Language Level.** Finally, analyses were conducted to determine 1) whether there were any differences in the way the younger and older infants responded and 2) whether there was any relation between infants’ imitative abilities and their level of vocabulary production. Infants’ age in days at the time of testing was correlated with each of the measures discussed above (i.e., percentage of intentional and accidental actions overall and by condition, and percentage of each type of response in each condition). There were no significant correlations, indicating that there was no clear developmental trend during this age range. There also were no significant correlations between infants’ scores on the vocabulary checklist and their performance on the imitation tasks.

**DISCUSSION**

Infants in this study watched an adult perform sequences of two actions on objects which were followed by interesting results. Some of the adult’s actions were marked vocally as intentional, some were marked as accidental. Results indicated that the infants imitated significantly more of the intentional than the accidental actions. These results thus provide evidence of an ability to distinguish intentional from accidental actions at a younger age than previously demonstrated (i.e., in Tomasello and Barton’s, 1994, study of 2-year-olds). In addition, the infants in this study were, on average, two months younger than Meltzoff’s (1995) 18-month-olds, who showed evidence of understanding intentional actions in a different paradigm (and some of the successful infants were four months younger).

In order to succeed at the current task, as in Meltzoff’s (1995) study, infants had to 1) interpret the adult’s overall behavior as intentional (e.g., the adult was acting with the goal of turning on the light), and 2) reproduce only the adult’s intended actions without mimicking exactly her “surface behavior,” or what she actually did. That is, infants in this study could have reproduced the adult’s actions exactly (even with the words she used) and still produced the end result because the result was activated if infants reproduced the intentional action(s), regardless of whether they reproduced the accidental ones as well. However, they chose instead to reproduce for the most part only those actions the adult had marked as intentional, skipping over her accidental actions. Whether the infants made a choice following the demonstration (i.e., “she didn’t mean to do A so B must be what I should do”) or whether infants did not really “see” or register the accidental actions in the first place (as is sometimes the subjective experience of adults) is unknown. What is clear is that infants seem to understand something about the intentions of others before age 18 months and that they use this understanding to make sense of others’ behavior.

Whereas infants imitated more of the adult’s intentional than accidental actions, they nonetheless did reproduce some of the accidental actions. There are several reasons why this might be the case. For example, because infants were not given a chance to interact with the objects before the adult’s demonstrations, they may have reproduced some of the adult’s actions simply because they looked like fun, irrespective of the adult’s intentions and/or the relation between the actions and the end result. Because the conditions to which actions were assigned were randomized, infants’ tendencies
to reproduce actions for fun would not have affected their differential imitation of the intentional actions across experimental conditions. Infants also saw a total of eight “accidents” during the course of their visit. The high rate of accidents may have called infants’ attention to the accidental actions and decreased their perceived status as accidental.

Another procedural factor that may have increased the number of accidental actions infants reproduced was the relative subtlety of the differences between the accidental and intentional versions of the modeled actions. In natural situations, accidental actions may be quicker, less definite, and thus less salient than intentional actions. We attempted in this study to reduce these differences somewhat by making actions look very similar across conditions, with the main difference being the vocal markers used. This was done for purposes of experimental control, so that any differences found in infants’ tendency to imitate intentional versus accidental actions could not be attributed to the timing or saliency of the actions. Given the barely verbal status of these infants, the lack of obvious or exaggerated physical cues about the adult’s intentions (which normally are present in more natural situations) may have made it more difficult for infants to distinguish between them. Whereas an adult who was blind to the condition of the modeled actions often could guess whether the actions were modeled accidentally or intentionally using only visual cues, it appears as though infants did not use this information, as their rates of responding correctly and incorrectly were almost identical when the adult was correct. Infants thus seemed to be relying primarily on the vocal markers of intentionality provided by the experimenter.

There are several other methodological factors that may have affected our results. First, this was a difficult task in that whereas many previous studies of imitation (e.g., Carpenter et al., in press; Meltzoff, 1995) gave infants three demonstrations of a single action before each response period, infants in this study responded after seeing a demonstration composed of two actions only once. There also were several indications that reproducing a sequence of two actions, as opposed to a single action, was difficult for these infants (as it is for most infants of this age, Bauer & Hertsgaard, 1993). During the training period, most of the infants had more trouble reproducing two actions than one and during the test trials, too, infants in the majority of their responses—67.6% across all three conditions—imitated only one of the two modeled actions. Still, when infants reproduced only one of the two modeled actions in the A-I and I-A conditions, it was significantly more often the intentional one. In addition, even though reproducing a sequence of two actions was difficult for these infants, they nevertheless responded in this way more often when it was the correct response (in the I-I condition) than when it was not (in the other two conditions).

The combination of different patterns of responding in different conditions and the fact that infants did not improve across the session or across repeated presentations of individual objects makes purely methodological explanations of our results implausible. It thus appears that before age 18 months, infants have a relatively advanced understanding of others’ intentions. During the 9 to 12 month period, they first show evidence of understanding that others have intentions and that these intentions may differ from their own (see Tomasello, 1995 for a review). The earliest evidence we have of the more complex understanding that others’ intentions may differ from the reality of the situation (an understanding that is analogous to that of false belief), is in 14- through 18-month-olds.

This understanding of others’ intentions is one of the first steps in the development of a theory of mind and an adult-like understanding of other persons (Tomasello, 1995). Moreover, the results demonstrate that when attempting to reproduce the actions of others, infants at this age quite often are able to “screen out” others’ unintentional, meaningless actions. This is an important ability because many of the most significant cultural skills that children...
must master during the toddler and preschool periods—including language and other cultural conventions—can only be acquired via the imitative learning of the intentional actions of other persons.

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NOTES

1. Because conditions and actions were randomized and not counterbalanced, we checked to make sure that actions were evenly distributed in terms of order and condition for each object. They were: all six 3 (condition) x 2 (order of actions) χ²’s were not statistically significant.

2. During the training period, most of the infants had more trouble reproducing two actions than one: whereas 15 of the 20 infants reproduced the single action modeled on the first training object without teaching, only 6 infants reproduced the sequence of two actions modeled on the second training object without teaching. After teaching, however, all 20 infants reproduced one action and 18 of the 20 reproduced two.

3. At least one trial was dropped for six of the infants, with a total of nine dropped trials. Five of the dropped trials were due to procedural errors (mechanical failures and experimenter error) and in one case an infant was frightened by the end result. The first three trials of another infant’s visit were dropped because his mother informed us at that point that they used “uh oh” for accidents instead of “woops” (“uh oh” was used for the rest of that infant’s visit).

4. No Response trials (i.e., trials in which infants did not reproduce either of the modeled actions) made up only a small percentage of the total trials: on average, the overall percentage of no response trials was 6.3% (5.0% for the I-I condition, 8.8% for the I-A condition, and 5.0% for the I-I condition). Including these trials in the total trials resulted in an identical pattern of statistically significant results to those reported below.

REFERENCES


Phillips, W., Baron-Cohen, S., & Rutter, M. (1992). The role of eye contact in goal detection: Evi-

APPENDIX

<table>
<thead>
<tr>
<th>Object</th>
<th>Action(s)</th>
<th>End Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>wooden box</td>
<td>press doorbell, twang spring</td>
<td>lights</td>
</tr>
<tr>
<td>wooden box</td>
<td>lift doorstop, twang spring</td>
<td>toy appears</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Object</th>
<th>Action(s)</th>
<th>End Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>wooden bird feeder</td>
<td>hit top up, pull ring</td>
<td>party favor</td>
</tr>
<tr>
<td>blue wooden box</td>
<td>pull handle up, spin wheel</td>
<td>toy appears</td>
</tr>
<tr>
<td>metal duct</td>
<td>lift front, hit attached circle</td>
<td>lights</td>
</tr>
<tr>
<td>newspaper recycler</td>
<td>push hinge, pull string</td>
<td>toy appears</td>
</tr>
<tr>
<td>colored wooden box</td>
<td>spin spinner, lift hinge</td>
<td>party favor</td>
</tr>
<tr>
<td>aluminum-can crusher</td>
<td>slide attached door-bolt, depress front of crusher</td>
<td>lights</td>
</tr>
</tbody>
</table>

Note: Lights were sets of colorful Christmas-tree lights that were turned on for several seconds; toys were small toys (e.g., balls with bells inside) that were lowered from their hiding place (an inverted box - see Figure 1) by a string, dangled, and then suddenly pulled back up into the hiding place by the string; party favors were air-powered poppers that were inflated by a pump several times. Each wooden box, toy, light set, and party favor was decorated differently.