Child Development, May/June 2007, Volume 78, Number 3, Pages 806 – 824

Doing the Right Thing: Infants' Selection of Actions to Imitate From Observed Event Sequences

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Two studies were conducted to investigate how 14- to 16-month-old infants select actions to imitate from the stream of events. In each study, an experimenter demonstrated two actions leading to an interesting effect. Aspects of the first action were manipulated and whether infants performed this action when given the objects was observed. In both studies, infants were more likely to imitate the first action when it was physically necessary to generate the effect, and in Study 2 they were also more likely to imitate the action when it was socially cued. It seems that infants' own knowledge of space and causality as well as their sensitivity to others' social signals both contribute to their tendency to imitate actions.

Manipulating and exploiting objects as tools is a defining characteristic of being human. Although some other species use and even make tools (Lea, 1999; Tomasello & Call, 1997), no other species is as dependent on tool-use as humans are or uses as wide a variety of tools. Implements of war and ritual, body adornments and grooming devices, artifacts for collecting and preparing food, and even items intended purely for entertainment are integral to the lifestyle of every group of humans ever described. Even young children know how to exploit many common objects. For example, in American culture typical 2- and 3-year-olds can effectively use spoons and drinking cups, washcloths and hair brushes, crayons and Scotch tape, and even TVs, CD players, and computers.

Developmental psychologists have attempted to account for the early appearance of such object-exploitation skills. In the seminal work on the topic, Piaget (1952, 1954) argued that children's tool-using skills are predicated on their emerging understanding of physical causality and spatial relations, and there is some empirical support for this idea. For instance, choice-paradigm research has shown that infants and toddlers appreciate perceptual features (e.g., rigidity) and spatial arrangements (e.g., contact) that make a tool or tool-using solution effective (cf. Bates, Carlson-Luden, & Bretherton, 1980; Brown, 1990; Leeuwen, Smitsman, & Leeuwen, 1994; Schlesinger & Langer, 1999; Willatts, 1984). Similarly, research using the preferential looking paradigm suggests that very young infants may be sensitive to certain principles of causality, contact, and support that are integral to tool-use (cf. Baillargeon, Needham, & DeVos, 1992; Kim & Spelke, 1992; Kotovsky & Baillargeon, 2000; Leslie, 1984; Leslie & Keeble, 1987; Needham & Baillargeon, 1993).

Recently, though, various forms of cultural transmission, and especially observational learning, have increasingly been implicated in the acquisition of object-related skills (Donald, 1991; Rogoff, Mistry, Goncu, & Mosier, 1993; Tomasello, 1999). Imitating the successful actions of others is an extremely efficient and safe way to learn complex behaviors, and observational learning can also explain the fact that children and even adults routinely exploit many objects without really comprehending how they physically work. Moreover, infants and young children typically have ample opportunities to observe other people using many commonplace tools, utensils, and machines. Indeed, at least in western cultures, adults frequently demonstrate objects and highlight their critical features for infants (Brand, Baldwin, & Ashburn, 2002; Lockman & McHale, 1989; Rogoff et al., 1993). Finally, human infants seem to be ready and willing to imitate the actions of

Study 1 was part of the first author's Ph.D. dissertation, submitted to Tufts University. We are grateful to Linda Acredolo for sharing her facilities at the University of California, Davis for portions of this data collection. Study 2 was part of the second author's master's thesis, submitted to Tufts University. We thank Erika Brent, Jenn Brown, Ann Marie Camuti, Jonathan Cohen, Lauren Cresci, Sarah Deeb, Nick Desai, Rachael Fuchs, Nora Joyce, Alex McCauley, Brie Moore, Michelle Nilsson, Janna Pahnke, Heather Ransom, Angie Rodday, and Maya Rodriquez for their help in testing infants and scoring data tapes. We also extend our gratitude to the participant families. Finally, we acknowledge Stephen Want for reviewing the original manuscript and suggesting the intermediate role of imitation discussed in this article.

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 0009-3920/2007/7803-0010

others at a very young age. Meltzoff and Moore (1977, 1983, 1989) have established that infants only a few days old can imitate facial gestures, and this imitative ability extends to behaviors with objects at 6 to 9 months of age, basically as soon as infants are able to act on objects intentionally (Kaye, 1982; Kaye & Marcus, 1978, 1981).

With regard to the development of tool use, the results of several studies specifically highlight the ''added value'' of imitation, above and beyond whatever insights children might already have from their early understandings of space and causality. Both Bushnell and Boudreau (1998) and Chen and Siegler (2000) described research showing that toddlers rarely obtained out-of-reach toys with a novel tool spontaneously, but did so easily when a model demonstrated using the tool first. Likewise, in many studies of imitation, infants in no-demonstration control conditions act upon the stimulus object(s) in various ways, but they exhibit particular target behaviors significantly less frequently than infants who have seen an experimenter model the target behavior first (cf. Barr, Dowden, & Hayne, 1996; Bauer, Hertsgaard, & Dow, 1994; Bushnell & Sidman, 2002; Meltzoff, 1985).

Thus, imitation is an effective mechanism for novices to learn object-related skills, particularly when they do not know beforehand what an object is for and cannot understand through insight how a toy or a tool physically works. However, learning object skills by imitation also poses some considerable cognitive challenges. In everyday life, adults' observable activities with objects are typically embedded in a constantly flowing stream of overlapping actions. An initial task for infants is to segment this continuous stream into discrete units that correspond to genuine events and intentional acts. This task is analogous to parsing the sound stream into words in language and to organizing the visual scene into coherent objects in vision. Both Wynn (1996; Sharon & Wynn, 1998) and Baldwin (Baldwin & Baird, 1999; Baldwin, Baird, Saylor, & Clark, 2001) have investigated infants' perception of action streams. Using dynamic stimuli and clever adaptations of the habituation paradigm, they have shown that 6-month-olds and 10- to 11-month-olds can extract meaningful action units from such streams.

Once an action stream is effectively parsed into individual units, an observer must then determine which of the actions are important to the goal at hand and which are incidental or irrelevant. That is, ordinarily it is not necessary for observers to reproduce all the actions they see. For example, an adult taking golf lessons need not imitate the instructor clearing his throat or scratching his knee, but probably should imitate his stance and his grip on the club. For imitation to be the efficient learning mechanism that it is, learners must have some strategies for determining which actions are important to imitate and which can be ignored. This ''selection'' problem can be illustrated for infants if one imagines a mother showing her young daughter how to play music on a toy tape player. Suppose the mother first dries her hands on a dish towel, then goes and sits next to the baby, straightens the tape player, pats the cat who is sitting nearby, picks up a tape and inserts it into the player, brushes some lint off the top of the player, wipes her hand on her pants, and finally pushes the play button that starts the music. With such a scenario, it would not be surprising if the baby later inserted a tape and pressed play to start some music for herself. But given this stream of many events, and assuming the baby does not already understand the mechanisms of the tape player, how did she know which actions were the crucial ones to reproduce? Why did she not search for the cat to pat, brush the top of the player, or wipe her hand on her pants?

Selecting actions to imitate is in some ways analogous to the problem children confront in lexical acquisition. Just as infants observe interesting effects embedded in the midst of a variety of actions, they hear novel words uttered in the presence of numerous possible referents. Yet despite the potential for errors, infants are remarkably adept at narrowing down the choices and mapping novel words to their correct referents. Researchers have established that infants succeed at lexical mapping because they rely on various assumptions about word labels (see Golinkoff, Mervis, & Hirsh-Pasek, 1994; Markman, 1992; Woodward & Markman, 1998), they follow certain perceptual and cognitive biases (Graham, Baker, & Poulin-Dubois, 1998; Jones, Smith, & Landau, 1991; Landau, Smith, & Jones, 1988), and they monitor certain social cues such as where the speaker is looking and what the speaker's intentions are (Baldwin, 1993; Tomasello & Barton, 1994; Tomasello, Strosberg, & Akhtar, 1996). We think that young children must similarly rely on various biases, nascent beliefs about causality and agency, and social signals in order to select actions to imitate from the stream of events. The purpose of the research reported here was to investigate what some of these constraining factors may be.

Prior work on selective imitation has focused mainly on characteristics of the model. For instance, Bandura (1971) showed that young children are most likely to imitate models who are warm, competent, and powerful (Bandura, 1971, 1977; Bandura, Ross, & Ross, 1963), and others have shown that children imitate older siblings more than younger ones (Abramovitch, Corter, & Pepler, 1980; Pepler, Abramovitch, & Corter, 1981) and friends more than disliked peers (Hartup & Coates, 1970). A few studies have also investigated aspects of the actions to be imitated. Thus Killen and Uzgiris (1981) found that 10- and 16-month-olds imitated conventional actions more than unconventional ones, and Carpenter, Akhtar, and Tomasello (1998) found that 14- to 18-month-olds imitated actions verbally marked as intentional more than those marked as accidental. Recent work has also shown that both infants (Carpenter, Call, & Tomasello, 2005) and young children (Bekkering, Wohlschlager, & Gattis, 2000) are more likely to imitate the ''manner'' of an action (e.g., to use the same movement trajectory or the same hand as the model had) when the action is executed for no apparent reason than when there is an obvious external goal to the model's action. In the past research most closely related to the selection issue introduced here, Harnick (1978) and Bauer (1992) examined infants' tendencies to imitate ''irrelevant'' actions in the context of goal-directed behaviors. Harnick found that infants tended to imitate irrelevant actions when the task was moderately difficult but not when it was trivially easy or extremely difficult, and Bauer found that infants imitated irrelevant actions less frequently than obligatory ones and were also more likely to produce them out of order. These results provide some support for the idea that infants selectively imitate actions according to whether or not they are critical to produce a goal. The question is, on what basis did infants judge the actions to be irrelevant?

One possibility is that infants' interpretation of action sequences might be shaped by how they understand and expect objects to interact. That is, infants might select actions to imitate according to their current beliefs about causality and other aspects of the physical world, just as they use their current knowledge and vocabulary as ''bootstraps'' in learning new words. A second possibility is that infants might rely on signals given by the model to assess an action's relevance to a goal, in a process akin to social referencing. These two potential influences on infants' selection of actions to imitate were examined in Study 1 and Study 2, respectively.

Study 1

In Study 1, we investigated whether infants' selection of actions to imitate is predicated on their knowledge of the physical world. Infants were shown sequences of two actions directed toward an object where an interesting effect then ensued. In the *necessary* condition, the first action had to be executed in order for the second action to then yield the effect; however, in the *unnecessary* condition, the first action was not integral to generating the result. In these conditions, whether the first action was necessary or not hinged primarily on the location of the first action with respect to the second. The specific action configurations are described in the methods section below and were designed according to research on infants' understandings of barriers, solidity, and containment (Hespos & Baillargeon, 2001; Sitskoorn & Smitsman, 1995; Spelke, Breinlinger, Macomber, & Jacobson, 1992). If infants apply what they know about these physical concepts as they observe event sequences, they should recognize the first action's importance in the necessary condition and its insignificance in the unnecessary condition. Accordingly, we predicted that infants would be more likely to imitate the first action in the necessary condition than in the unnecessary one.

Infants' behavior in the necessary and unnecessary conditions was also contrasted with their behavior in a third condition, the *off-object* condition. In this condition, as in the unnecessary one, the first action was not integral to producing the effect. Furthermore, in the off-object condition, the first action was not even directed toward the object where the effect ensued. Instead, the experimenter modeled an action directed toward her own body in some cases and toward a separate object in other cases, before then modeling the second action directed toward the object where the effect happened. This condition and its comparison with the other two is based on findings that suggest that infants consider a physical connection integral to causality. For example, research with Michottian event sequences indicates that by about 6 months of age, infants perceive one object to exert a causal influence on another only if there is physical contact between them (cf. Cohen & Amsel, 1998; Kotovsky & Baillargeon, 2000; Leslie, 1984). Similarly, by 8 months of age, infants are more likely to pull a cloth toward them when there is a toy on the cloth than when the toy is next to the cloth (Schlesinger & Langer, 1999; Willatts, 1999). Given this role attributed to physical contact, it seems that in their efforts to recreate an interesting effect, infants might preferentially imitate actions directed toward the object involved in the effect and rule out actions directed elsewhere. Therefore we predicted that infants would be less likely to imitate the first action in the off-object condition than in the other two conditions, in which the first action as well as the second were directed toward the object where the result occurred.

Method

Participants. Forty-two healthy 15-month-olds (M = 15 months 3 days; SD = 4 days) participated in the study. Twenty-two were females and 20 were males. All participants were recruited from the local community by mail solicitations to parents; most participants were Caucasian but the sample also included 2 Hispanic infants. All infants contributed at least some data to the final sample. However, the necessary trials of 4 infants could not be included because of an equipment failure (1), parental or sibling interference (2), or lack of cooperation to the extent that the infant did not even observe the actions modeled (1). Similarly, the unnecessary trials of 3 infants could not be included, 2 because of interference and 1 because of lack of cooperation. Finally, the off-object trials of 4 infants could not be included because of experimenter error (1), interference (1), and lack of cooperation (2).

Design. During their experimental visit, each infant participated in three immediate imitation trials, each with a different novel toy. On each trial, the experimenter deliberately demonstrated two distinct actions that led to an interesting effect. In all conditions, the second action was performed on the object where the effect occurred and was required to produce the effect. In the *necessary condition*, the first action was also performed on the object where the effect occurred and was required for the effect. In the *unnecessary condition*, the first action was again performed on the object where the effect occurred, but it was not needed to produce the effect. In the *off-object condition*, the first action was also not needed for the effect, nor was it performed on the object where the effect occurred. Because the off-object condition was somewhat exploratory, there were two variants: in the *remote* version, the first action was performed on a separate object from where the effect occurred, and in the *body* version, the first action was performed on the experimenter's body (e.g., patting her head). It is important to note that for any given toy, the second action and the effect were identical in each condition. Likewise, the first action was identical in the necessary and unnecessary conditions, as well as in the remote version of the off-object condition; across these conditions the first action was just performed in a different location, making it either necessary or not to achieve the final outcome.

Each child was shown one toy in the necessary condition, one in the unnecessary condition, and one in the off-object condition. Initially, most infants were presented with the body version of the off-object condition. However, the results for this were so patently obvious that we developed the remote variant of the off-object condition and used it for the majority of infants in the sample. Across infants, the three novel toys used served equally often in each condition. The order of the three conditions was also structured such that across infants, each condition was presented equally often before and after each other condition.

Materials. Three novel toys were developed for Study 1: the *flower box*, the *ramp*, and the *rake*. Furthermore, there were three variants of each toy to accommodate the different experimental conditions. For example, the flower box was a colorful wooden box with a lid that could be pulled open with a knob to reveal an array of plastic flowers (see Figure 1b). In the necessary condition, the lid was held shut by a Velcro latch that could be undone by pulling on another wooden knob (see Figure 1a). Thus, for the flower box, undoing the latch was the first action modeled by the experimenter (action A) and opening the lid was the second (action B); the goal was seeing the flowers. In the unnecessary condition, the latch was positioned on the other half of the box top (see Figure 1c). It therefore did not hold the lid shut, but the experimenter undid the latch before opening the lid anyway. In the remote version of the off-object condition, a smaller wooden block was placed next to the unnecessary flower box (see Figure 1d), and the experimenter opened a Velcro latch on this block before opening the lid on the main box. In the body version, the unnecessary box was presented alone and the experimenter patted her head several times with her hand before opening the lid. In both off-object variants, the Velcro latch was present in the unnecessary position on the flower box, but the experimenter did not manipulate it in any way.

The several variants of the ramp and the rake are shown in Figures 2 and 3, respectively. For the ramp, removing a cardboard barrier was the first action modeled by the experimenter (action A) and placing a ball in a hole at one end was the second (action B); the goal was seeing the ball roll down the tube and come out at the bottom. The necessary and unnecessary conditions were created by having the barrier "downhill" and "uphill" to the ball's path, respectively. For the off-object condition, there was no barrier in the tube where the ball was placed; instead, for the remote variant, the experimenter removed a barrier on a separate smaller tube for action

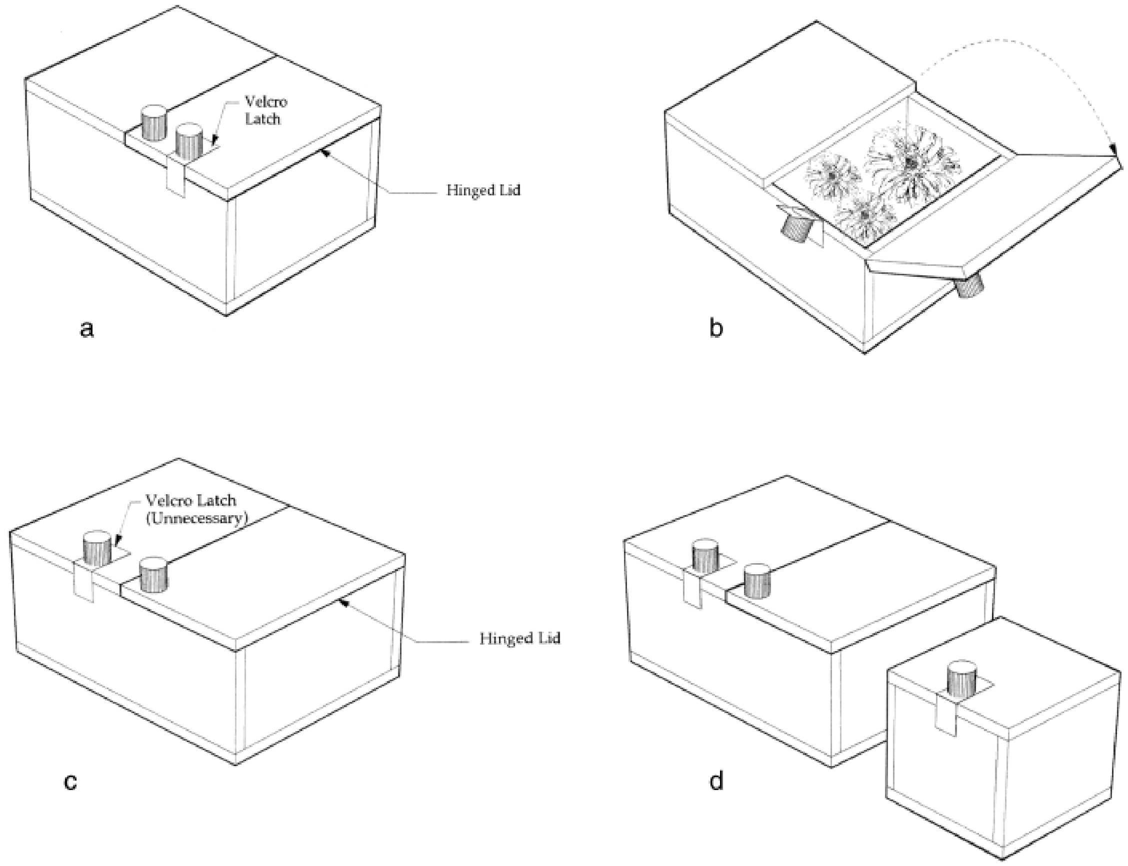

Figure 1. The flower box stimulus used in Studies 1 and 2. (a) The flower box as it was presented to infants in the necessary condition. (b) The flower box after actions A and B have been performed. (c) The flower box as it was presented to infants in the unnecessary condition. (d) The flower box as it was presented to infants in the remote version of the off-object condition.

A, and for the body variant, she touched the ball to her nose several times before placing it in the hole of the tube. For the rake, pushing in a plastic tray to close a pit trap in a box top was the first action modeled by the experimenter (action A) and pulling on a T-shaped paddle on the box top was the second (action B); the goal was obtaining an out-of-reach toy. The necessary and unnecessary conditions were created by starting with the toy on the box's side with and without the pit trap, respectively. For the off-object condition, the pit trap in the main box was closed to begin with; in the remote variant, the experimenter closed a trap in a smaller separate box for action A, and for the body variant, she patted her head several times with her hand before pulling on the paddle.

Procedure. Upon arrival at the lab, the parent was asked to fill out a consent form while the experimenter established a rapport with the infant. During this warm-up phase, the experimenter passed several toys back and forth with the infant and commented on them as she did so, to set up the general routine for the experimental trials. The parent and child were then seated at a table, with the baby on the parent's lap and facing a two-way mirror. The experimenter also sat at the table 90° to the baby's right. The entire session was recorded with a video camera on the other side of the mirror. Once everyone was settled, an assistant set the object(s) for the first trial down between the infant and the experimenter and out of the child's reach. The experimenter said, "(Baby's name), watch what I do," and then she performed the appropriate two-action sequence in a slow, deliberate fashion. She then said, "OK, watch me again" and performed the sequence a second time. The experimenter then pushed the toy(s) toward the infant saying, "Would you like to try it?," and the infant was given 30 s to interact with the toy. After the baby's turn, the toy was removed and the assistant brought out the materials for the next trial. The second and third trials followed the same procedure as for the first trial.

Coding and analyses. Each child's interactions with the toys were later coded from videotape by one of

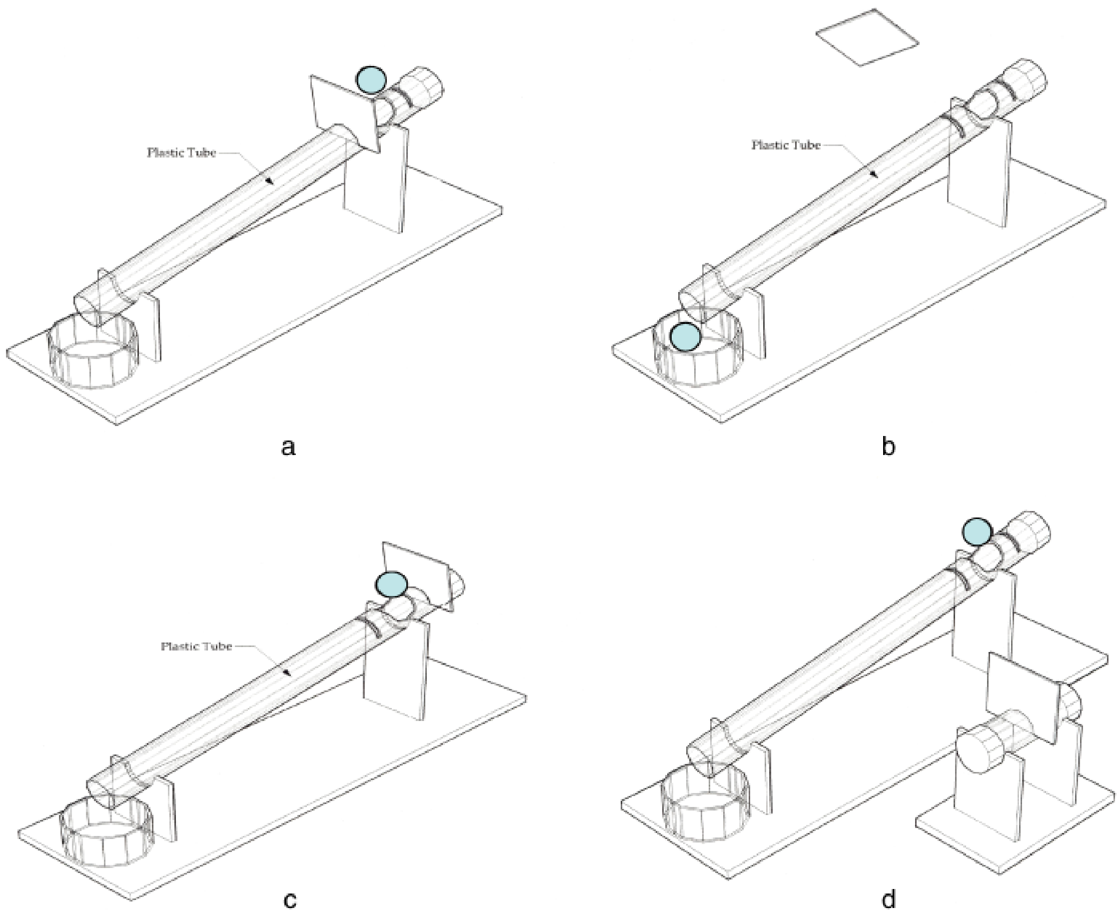

Figure 2. The ramp stimulus used in Study 1. (a) The ramp as it was presented to infants in the necessary condition. (b) The ramp after actions A and B have been performed. (c) The ramp as it was presented to infants in the unnecessary condition. (d) The ramp as it was presented to infants in the remote version of the off-object condition.

two undergraduate assistants. These students had been trained to code for the target actions A and B that the experimenter had demonstrated for each toy and condition. Infants were credited with having done the target actions only if they actually executed the action and not if they simply touched the appropriate part of the object (e.g., with the flower box, the lid had to move at least slightly upward indicating an actual pull on the knob; with the ramp, the ball had to be released into the hole rather than just held over it, etc.). The coders also recorded when each target action was performed on a timeline representing the 30-s trial, so that the order in which infants performed the two actions (if they performed both) could be assessed. While it was impossible to keep coders blind to the condition being tested (because the toys were visible on the videotapes), the coders were not familiar with the purpose or hypotheses of the study. In order to calculate intercoder agreement between the two coders, 10 of the infants' sessions (24% of the sample) were scored by both coders independently. The two coders agreed 100% of the time on which target actions were performed and on the order in which they were performed.

Results

The primary question in Study 1 was whether infants would imitate the first action modeled by the experimenter (action A) in some conditions but not in others. The frequencies and orders in which infants performed the two target actions in each condition are shown in Table 1. It can immediately be seen that infants performed action A most frequently in the necessary condition, occasionally in the unnecessary condition, and hardly ever in the off-object condition, including absolutely never in the body variant. This pattern held for each of the three toys, although with the ramp toy a high proportion of infants performed neither action A nor B, because

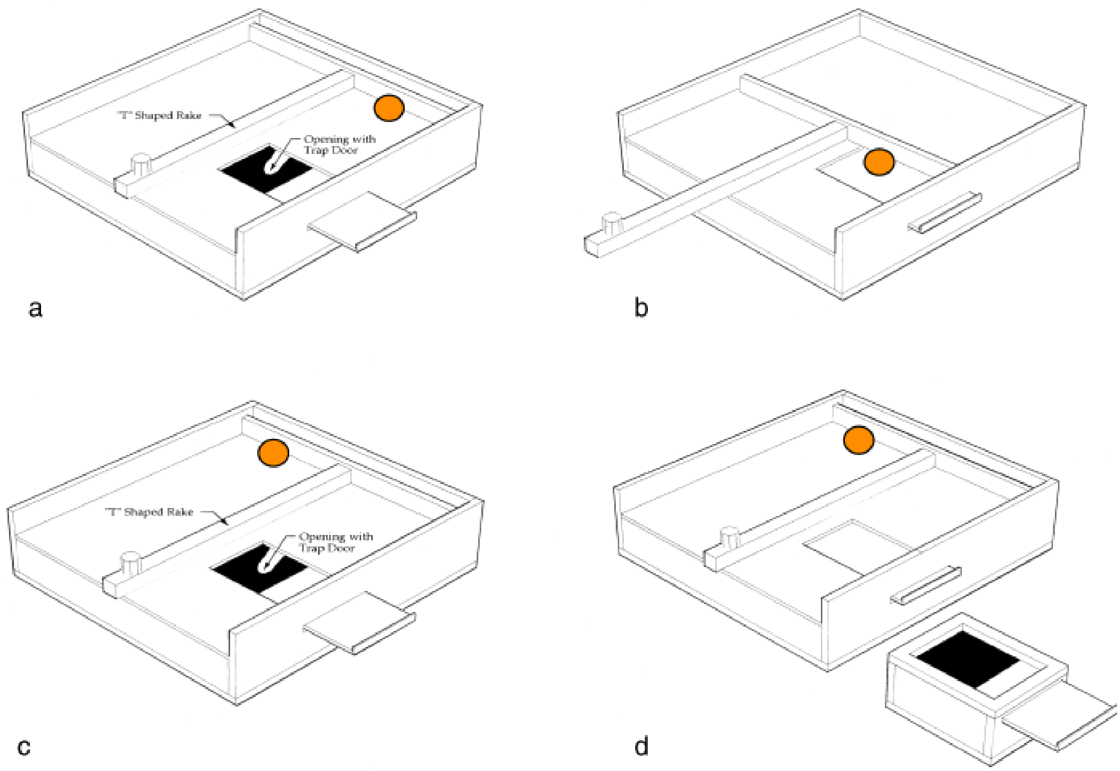

Figure 3. The rake stimulus used in Study 1. (a) The rake as it was presented to infants in the necessary condition. (b) The rake after actions A and B have been performed. (c) The rake as it was presented to infants in the unnecessary condition. (d) The rake as it was presented to infants in the remote version of the off-object condition.

they became preoccupied with alternative activities with the ball and would not release it into the hole.

To statistically compare infants' behavior in the different conditions, a Cochran *Q* test was conducted analyzing whether infants had versus had not performed action A in each condition. The Cochran *Q* test is the equivalent of a repeated measures (within-subject) analysis of variance, except that it is used with dichotomous data such as in Study 1. This analysis yielded a significant effect, indicating that action A was performed with different frequencies across the three conditions, Q ($df = 2$, $n = 34$) = 13.15, $p < .01$. We also conducted a second Cochran *Q* test analyzing whether infants had performed action A *first* (i.e., they did A only or they did it before B) versus either not at all or after action B. This scheme was used because when infants performed A after B, they had already achieved the goal right after completing B in the unnecessary and off-object conditions, and hence we could not suppose that they construed A as integral to the goal. The second Cochran *Q* test also yielded a significant effect, indicating that infants performed action A first with different frequencies across the three conditions, Q ($df = 2$, $n = 34$) = 13.13, $p < .01$.

To further explore the condition effect identified with the omnibus analyses described above, a series of McNemar tests was conducted to compare each

Table 1
Numbers and Percentages of Infants Performing Particular Sequences of Target Actions in Each Condition in Study 1

Condition	A only		A then B		B only		B then A		Neither	
Necessary	8	21%	11	29%	7	18%	3	8%	9	24%
Unnecessary	2	5%	7	18%	13	33%	4	10%	13	33%
Off-object	2	5%	2	5%	22	58%	2	5%	10	26%
Remote variant	2	9%	2	9%	13	57%	2	9%	4	17%
Body variant	0	0%	0	0%	9	60%	0	0%	6	40%

condition with each other condition individually. The McNemar test is a nonparametric procedure similar to the chi-square test but designed for use with within-subject data. It is used to compare behavior in two conditions by assessing whether more infants "pass" (in this case perform action A) in the first condition but not in the second compared with the number of infants who pass in the second condition but not in the first. Infants who pass (perform action A) in both conditions or in neither condition do not figure in the statistical procedure.

The McNemar tests showed that infants were more likely to do action A in the necessary condition than in any of the other conditions or variants thereof. While 13 infants performed A in the necessary condition but not in the unnecessary one, just 4 performed A in the unnecessary condition but not in the necessary one, $\chi^2(df = 1) = 3.76$, $p < .05$. Similarly, 19 infants performed A in the necessary condition but not in the off-object one, but just 3 performed A in the off-object condition but not in the necessary one, $\chi^2(df = 1) = 10.23$, $p < .01$. The comparable numbers for the comparisons between the necessary condition and each variant of the off-object condition were 10 and 3 for the remote variant, $\chi^2(df = 1) = 2.77$, $p < .05$, and 9 and 0 for the body variant (binomial $p = .002$). An analogous series of McNemar tests based on whether infants performed action A first or not in the necessary condition versus the others was also conducted, because of the concern mentioned earlier that instances of A performed after B are ambiguous to interpret. These tests yielded very much the same pattern of results as those just described for whether action A was simply performed or not (regardless of order).

Although relatively few infants performed action A except for in the necessary condition, we nevertheless also used McNemar tests to compare infants' behavior in the unnecessary condition with that in the off-object condition and its two variants. Overall, there were 10 infants who performed action A in the unnecessary condition but not in the off-object one and just 4 who did the converse; this comparison is marginally significant, $\chi^2(df = 1) = 1.79$, $.05 < p < .10$. The comparable numbers for the comparisons between the unnecessary condition and each variant of the off-object condition were 6 and 4 for the remote variant and 4 and 0 for the body variant; the distribution for the remote variant is not statistically significant and the numbers involved in that for the body variant are too small for statistical analysis. As with the necessary condition, analogous analyses based on whether infants performed action A first or not in the unnecessary condition versus in the off-object one and its variants were also conducted. These tests yielded very much the same pattern of results as those just described for whether action A was simply performed or not (regardless of order).

Discussion

The results of Study 1 establish that infants' imitation of actions from the event stream is selective and may be predicated on their understanding of space and physical causality. Although the experimenter modeled action A in all conditions, infants performed A more frequently in the necessary condition than in any of the other conditions or variants where it was not integral to the goal. They also performed action A first (i.e., before action B) more frequently in the necessary condition than in any of the other conditions or variants. Note that except for its location with respect to the goal, action A was exactly the same behavior in the necessary, unnecessary, and remote variant of the off-object condition, and it was modeled with equal enthusiasm and solicitation of attention in all cases, too. Thus, whatever action A's inherent appeal or level of difficulty were, these were constant across the necessary, unnecessary, and remote event sequences, and yet infants performed A more frequently in the necessary condition. In prior work suggesting that imitation is selective, the actions infants excluded were verbally marked as irrelevant (e.g., Carpenter, Akhtar et al., 1998) or they were different altogether from the actions infants included (e.g., Bauer, 1992; Harnick, 1978). The results reported here show that infants may imitate the very same observed behavior or not, according to their own interpretation of its importance to an ensuing effect.

The condition effects observed in Study 1 speak to an issue currently under debate within the developmental and animal cognition literatures. In these fields, a distinction is made between reproduction of the means ("imitation") and reproduction of the ends ("emulation") in learning causal behaviors by observation (cf. Tomasello, 1990; Want & Harris, 2002). Tomasello (1990, 1999) has argued that unlike apes who are predominantly emulators, human infants and young children are inveterate imitators. To support this, he points to several instances in which infants and children reproduced a model's behavior with great fidelity, even when it was inefficient or unnatural to do so (Meltzoff, 1988; Nagell, Olguin, & Tomasello, 1993; Whiten, Custance, Gomez, Teixidor, & Bard, 1996). Tomasello attributes such "true imitation" to the unique ability of even young humans to perceive someone else's intentions. However, our results, similar to the recent findings of Gergely, Bekkering, and Kiraly (2002), show that infants do not always reproduce each intentional behavior a model performs. In the off-object condition, and to a lesser extent in the unnecessary condition, infants did not perform action A even though the experimenter had intentionally done so. Strictly speaking, they emulated the goal she achieved rather than imitated her means of achieving it.

Why did infants omit action A in the unnecessary and off-object conditions? This was *not* because 15-month-olds cannot remember or motorically execute the A behaviors, because many infants performed them in the necessary condition. Even for the body variant, where action A was a different behavior from in the other conditions, research on infants' gestures confirms that 15-month-olds are well able to do the behaviors involved—that is, to pat their heads or touch a ball to their noses (Acredolo & Goodwyn, 1988, 1990; Goodwyn, Acredolo, & Brown, 2000). Nor did infants omit action A because they did not see it or attend to it; the actions were modeled twice before infants had their turn, and the data of infants who were uncooperative to the point that they did not see each step of the demonstration were excluded from the analyses.

We think infants omitted action A in the unnecessary and off-object conditions because they did not consider it to be related to the effect they wanted to recreate. In other words, infants used their understanding of space and physical causality to analyze the sequence of events. Although they may perceive the experimenter's intentions as she acts, infants appear to "filter" her actions according to their own intentions, assessing each action for its importance to fulfilling these. From this perspective, infants seemed to presume that actions directed to the body are not related to effects occurring on a separate object, and hence they omitted action A in the body variant of the off-object condition. Similarly, they seemed to presume that actions directed toward one object are not related to effects occurring on another, and hence they omitted A in the remote variant. These supposed presumptions are consistent with research showing that young infants consider physical contact integral to causality. They are "surprised" and look longer at impossible, no-contact causal events contrived by experimenters (cf. Cohen & Amsel, 1998; Kotovsky & Baillargeon, 2000; Leslie, 1984; Schlesinger & Langer, 1999). Similarly, we might imagine that infants in the current study were perplexed to see action A in conjunction with the effect elsewhere, and omitted it on that account.

Infants also omitted action A in the unnecessary condition, at least relative to how often they performed it in the necessary condition. In both of these conditions, A was directed to the object where the effect occurred; hence, a bias favoring simple contact is not sufficient to account for this result. Instead, the crux of the matter in these conditions had to do with whether the part that moved in action B (e.g., the door for the flower box, the ball for the ramp) was on a "collision path" with the part manipulated in action A. Thus, assessing the role of A requires anticipating motion trajectories as well as appreciating particular spatial relations between objects, including the concepts of barriers, solidity, and containment. Findings from preferential looking studies suggest that by 12 months, if not earlier, infants do have some understanding of such relationships (cf., Hespos & Baillargeon, 2001; Sitskoorn & Smitsman, 1995; Spelke et al., 1992). In the necessary and unnecessary conditions, infants evidently analyzed the demonstrations in light of their understanding of these more complex spatial relationships, and then imitated action A in the one condition but not the other accordingly.

It is interesting that infants were able to bring their knowledge of physical reality to bear in the imitation context, in light of the fact that even older infants fail at analogous tasks requiring them to spontaneously act on their knowledge. Berthier, DeBlois, Poirier, Novak, and Clifton (2000) and also Hood, Carey, and Prasada (2000) found that 2-year-olds were no better than chance at searching for an object that rolled down an out-of-sight ramp and came to rest against a barrier whose location was visible. These results seem inconsistent with the selective imitation observed here in related tasks and with reports that very young infants exhibit prolonged looking when shown similar displays with the object unveiled in the "wrong" place (Spelke et al., 1992). Berthier et al. explain the disparity between manual task and looking task results by noting that searching by hand requires infants to localize the target object precisely and to coordinate their knowledge with action, while looking preferentially merely requires infants to recognize a perceptually anomalous event. The selective imitation observed here may reflect a level of knowledge intermediate to that demanded in these two situations. To imitate selectively, an infant must coordinate knowledge with action, as in the manual search task. However, they do not have to generate a solution spontaneously; as in the looking paradigm, the demonstration gives infants the opportunity to recognize "a good (or bad) solution when they see one." Kuczaj and Maratsos (1975) observed a similar role for imitation in language acquisition; their subject could imitate grammatical structures and even remedy incorrect versions modeled for him to imitate before he utilized the same structures in his spontaneous speech. Thus, imitation may serve a bootstrapping role for cognitive development in general; through the priming and recognition advantages it affords, imitation may prompt children to practice and consolidate tenuous knowledge structures to the point where they can ultimately be used spontaneously.

Finally, infants' behavior in the unnecessary condition must be considered further. In this condition infants performed action A less frequently than in the necessary condition, but also more frequently than in the off-object condition. In other words, in the unnecessary condition, infants did not omit action A as systematically as in other instances where it was likewise not integral to the effect. Infants in the unnecessary condition also performed action A more frequently than did a separate group of infants tested for other purposes who were simply presented with the toys without demonstrations. (Thirteen of 39 infants performed A after the demonstrations in the unnecessary condition—see Table 1, but just 2 of 24 infants merely presented with the toys in the unnecessary configuration ever performed action A). We surmise that the occasional inclusions of action A in the unnecessary condition may reflect some uncertainty about its relevance. After all, the spatial concepts important to assess A's role in the unnecessary condition are more subtle and complex than the simple matter of no contact available for the off-object condition. Perhaps when infants are not certain about the relation between an action and an effect, they adopt a fail-safe strategy and ''blindly'' imitate the action so as to be sure of producing the effect (see Want & Harris, 2002). Or perhaps it is precisely in such ambiguous instances that infants follow the social signals of the model, as Tomasello has emphasized and in accord with some conceptions of social referencing (Klinnert, Campos, Sorce, Emde, & Svejda, 1983; Uzgiris & Kruper, 1992).

If infants were unsure of action A's role in some instances and therefore followed the experimenter's apparent intentions, they would be led to perform A, because in Study 1, the experimenter deliberately demonstrated both A and B in all conditions. This deliberate demonstration involved looking at the toy and then looking at and talking to the infant before modeling the A–B sequence. Intuitively, this pattern of behavior is what adults typically do when they demonstrate objects to young children. Such bouts of joint attention may serve to ''frame'' the critical sequence of actions for the observing child and so give meaning to otherwise ambiguous actions. To explore this idea, we conducted a second study using the same two-step, elicited imitation procedure as before, and again manipulating whether the initial action was necessary or not. However, in Study 2 the critical manipulation was whether this initial action was socially cued or not. We predicted that infants would imitate action A more frequently when it was socially cued than when it was not cued.

Study 2

Method

Participants. Twenty-one 14- to 16-month-old infants (10 boys and 11 girls; mean age = 15 months 4 days, *SD* = 29 days) participated in Study 2. Infants were recruited from the local community by mail solicitations to parents; most of the participants were Caucasian but the sample also included two Hispanic and one Middle-Eastern infant. One other infant was also tested but was excluded from the final sample because he was extremely wary and did not interact with the toys at all. In addition, the two unnecessary trials of 2 infants were not included in the final sample because of a video failure in one case and uncooperativeness in the other. None of the infants in Study 2 had participated in Study 1.

Design. In Study 2, each infant participated in four elicited imitation trials, each with a different novel toy. On each trial, the experimenter deliberately demonstrated two distinct actions toward the toy, which then yielded an interesting effect. As in Study 1, the nature of the first action was manipulated. The primary contrast in Study 2 was whether the experimenter solicited the infant's attention before the first action or not. Thus, for two of each infant's four trials, the first action was *socially cued*, while for the other two, the first action was *not cued*. As a secondary issue, we also manipulated the causal nature of the first action as in Study 1. Thus, for two of the toys used, the first action was *necessary* for the effect to occur, and for the other two, it was *unnecessary*.

Each infant's four trials were blocked according to the causal nature of the toys. Half of the infants were presented with the two necessary toys first and half with the two unnecessary toys first. Within each of these blocks, one trial was socially cued and the other was not cued. The order of the socially cued and not cued trials within each block and also the particular toy used for each cueing condition was counterbalanced across infants. Thus, overall, each of the four novel toys served equally often in the socially cued and not cued conditions.

Materials. Four different cause-effect toys were used in Study 2, two for which the first action was necessary and two for which it was not. One of the unnecessary toys was the *flower box* used in the unnecessary condition of Study 1 (see Figure 1c). Recall that with this toy, the experimenter first undid a Velcro latch (action A) positioned such that it did *not* hold the box lid shut, and then she pulled a knob to open the lid (action B) and reveal the flowers inside (the effect). The ramp and the rake of Study 1 were not used in Study 2 because of attrition problems related to them in the previous study—some infants would not let go of the ball in the ramp task and some infants leaned over the pit to obtain the toy with their hands instead of with the rake in that task. Hence, another unnecessary toy for Study 2 was newly developed. It was a Fisher Price *tape player* with a large green start button on top and a Winnie-the-Pooh song loaded inside. Two brightly colored plastic tubes each about 10 cm long and 1.5 cm in diameter were fastened to one side of the tape player, and a thin yellow rod also about 10 cm long was placed in one of these tubes so that it protruded slightly. The experimenter first demonstrated taking the rod out of the one tube and placing it into the other (action A), and then she pressed the start button (action B) to make the music play (the effect). Moving the rod from one tube to the other had nothing to do with initiating the music; it was an unnecessary action we contrived to be directed toward the tape player and easy for infants to do.

The two necessary toys for Study 2 were also newly developed. One was modeled after the *rattle* item used by Bauer (e.g., Bauer & Hertsgaard, 1993) in her studies on temporal memory. The rattle involved the two halves of a plastic, snap-together barrel about 7 cm tall and 5 cm in diameter and also a small plastic block about 2 cm on a side. The experimenter started with the barrel halves separated, and she first picked up the block and placed it into one of the halves (action A). Then she snapped the two halves together (action B) and shook the barrel to generate noise (the effect). The other necessary toy was a battery-operated toy dog about 25 cm tall that we had rewired so that it could be made to bark (the effect) by first flipping a toggle switch (action A) and then pressing a button (action B). The dog, the toggle switch, and the button were all mounted on a wooden platform with the two manipulandums a short distance apart.

Procedure. The overall procedure was similar to that of Study 1. Infants sat at a table with their parent and the experimenter, who showed them demonstrations of the four toys, one by one. With each toy, the experimenter demonstrated the appropriate two-action sequence and effect in a slow deliberate manner and then offered the toy to the infant for a 30-s turn. If the infant generated the effect, the toy for the next trial was brought out and presented in a similar fashion. If the infant did not produce the effect, the experimenter helped the infant make the toy work for motivation's sake, and then the next toy was brought out. The entire session was videotaped with a camera positioned slightly off to the infant's right.

For toys presented in the socially cued condition, the demonstrations were given as in Study 1, that is, in a fairly natural manner. The experimenter looked at and spoke to the infant before performing action A ("Heh, what's this? Watch what I can do."), and she did so again before performing action B ("Did you see that? Now watch this."). She also commented on the effect after making it occur ("neat, huh"). When speaking to the infant before each step, the experimenter not only looked at the infant but also leaned in toward him or her and down to the infant's level. In the not cued condition, the experimenter did not solicit the infant's attention before performing action A. Instead, after she received the toy, the experimenter sat up straight, looked at the wall across the room, and said "Wow! It's nice outside. Spring's almost here." This sham utterance was approximately equal in length and intonation to the experimenter's initial comments to the infant in the socially cued condition, but the experimenter's posture and eye gaze did not indicate that she was talking to the infant. After speaking toward the wall, the experimenter then looked directly at the toy and performed action A. Then *after* performing A, the experimenter looked at and spoke to the infant for the first time on that trial ("Did you see that? Now watch what I do next"), and then she performed action B and also commented on the effect. Thus, the critical difference between socially cued and not cued trials was whether or not the experimenter spoke directly to the infant before performing action A and thereby marked it as being done for the infant's benefit. Action B was so marked in both conditions, and the effect was also commented on in both conditions as well.

Coding. The second author scored the video records of each infant's session for several behaviors. As in Study 1, the coder noted whether or not the infant performed the target actions A and B defined specifically for each toy. Infants were credited with having done an action only if they actually executed the action and not if they simply touched the appropriate part of the toy (e.g., not just picked up the block but placed it in a barrel half, not just touched the toggle switch but moved it, etc.). The coder also recorded when each action was performed on a 30-s timeline, so that the order in which infants performed A and B (if they performed both) could be assessed. In addition, the coder also reviewed the video records for two aspects of infants' looking behavior during the demonstrations. For each trial, she noted whether the infant looked at the experimenter as she vocalized (to them or to the wall) before action A, and whether the infant looked at the toy while the experimenter was performing action A. These variables were scored as additional measures that might indicate infants' sensitivity to the social cueing manipulation, along with the ultimate measure of whether or not they imitated action A.

To assess coding reliability, the trials of 6 infants (30% of the sample) were also scored by a second coder who had not been present during the testing and who was naïve with regard to the issues of interest. The coders agreed on all 24 trials (100%) with regard to whether infants performed action A, whether they performed action B, and the order in which A and B were performed. The coders agreed with regard to whether infants looked at the experimenter vocalizing before action A on 22 of the 24 trials (92%), and they also agreed with regard to whether infants looked at the toy during the demonstration of A on all but 2 trials (92%).

Results

Selective imitation of the target actions. As in Study 1, the main question in Study 2 was whether infants would selectively imitate action A, performing it in some conditions but not in others. The frequencies and orders in which infants performed actions A and B for each trial type in Study 2 are shown in Table 2. From Table 2 it can immediately be seen that infants performed *neither* of the target actions more frequently on the necessary trials than on the unnecessary ones. This difference was almost entirely due to the dog toy; unexpectedly, a number of infants became quite wary of the dog after the experimenter had made it bark, and they refused to interact with it! These refusals are quite different from the instances of ''neither'' in Study 1; those were distributed equally across the various conditions and represent cases where infants were actively involved with the stimulus objects but chose not to perform the target actions. Accordingly, for Study 2, we analyzed the data including only trials on which infants were willing to interact with the toy as evidenced by their performing at least one of the target actions. Otherwise, the comparisons between conditions would have been dominated by the differences in the ''neither'' column of Table 2, which are due to the refusals with the dog toy and thus of little relevance to the matter of selective imitation.

Considering all but the ''neither'' column of Table 2 then, it can be seen that almost all of the infants performed action A on the socially cued and necessary trial, while less than half of them did so on the not cued and unnecessary one. Infants' behavior on the other two trials was in between these extremes. These descriptive comparisons right away suggest that both the demonstrator's social signals and the infant's own appraisal of a behavior's meaning influence the selection of actions to imitate, perhaps in a sort of additive way. To statistically compare infants' behavior on the different trials, we first conducted a Cochran *Q* test, as in Study 1 analyzing whether infants had versus had not performed action A on each trial. Because the data from one or the other of their necessary trials were excluded for many infants as noted above, this analysis included only 9 infants. The results of this analysis did not indicate that action A was performed with different frequencies across the four trials, Q $(df = 3, n = 9) = 6.0$, $p > .05$. As for Study 1, we also conducted a second Cochran *Q* test analyzing whether infants had performed action A *first* as compared with after or only action B. This scheme was used because when infants performed A after B, they achieved the goal right after completing B with the

Table 2
Numbers and Percentages[a] of Infants Performing Particular Sequences of Target Actions for Each Condition and Type of Toy in Study 2

Condition	A only		A then B		B only		B then A		Neither	
Socially cued and necessary	6	43%	5	36%	2	14%	1	2%	7	—
Not cued and necessary	8	50%	2	13%	5	31%	1	6%	5	—
Socially cued and unnecessary	2	11%	9	47%	6	32%	2	11%	0	—
Not cued and unnecessary	1	5%	2	11%	10	53%	6	32%	0	—

Note. [a]Infants performing ''neither'' A nor B are not included in the calculations of percentages; see text for details.

unnecessary toys, and hence their performance of A could not have been predicated on an interpretation that it was integral to the goal. This second Cochran *Q* test also included only the 9 infants who had usable data for all four trials, but it did yield a significant effect, indicating that infants performed action A first with different frequencies across the four trials, Q ($df = 3$, $n = 9$) = 9.23, $p < .05$.

In order to further explore the role of the cueing manipulation, which was central to Study 2, and also to include data from all of the infants, we next examined the data collapsed across the two trials of each cueing type, regardless of their causal nature. Thus, considering their two socially cued trials together (one necessary and one unnecessary), infants were assigned a score based on the proportion of those trials on which they performed action A. This score was a 1 if an infant performed A on both of his or her socially cued trials (or on the one socially cued trial if data from the other could not be included); it was a .5 if an infant performed A on one of the socially cued trials but not on the other; and it was a 0 if an infant did not perform A on any of the socially cued trials. Infants were also assigned an analogous score based on their performance of A across their two trials that were not cued, and then their scores in the two cueing conditions were compared. The average score for performing A on the cued trials was .76, while the average on the not cued trials was .52. Nine infants had higher scores on the socially cued trials than on the not cued trials, while just one infant had a higher score on the not cued trials (the remaining infants' scores for the two trial types were tied). This distribution is significant by the sign test, binomial $p = .011$, indicating that over all four trials, infants were more likely to perform A on the socially cued trials as compared with on those that were not cued. We also performed the same kind of analysis but with the scores based on whether infants had performed A first (i.e., not after B) across their two trials of each cueing type. With this analysis, 13 infants had higher scores on the socially cued trials than on the not cued trials, while just 3 had higher scores on the not cued trials. This distribution is also significant by the sign test, binomial $p = .046$, indicating that in addition to being more likely to perform A in general, infants were also more likely to perform A first on the socially cued trials as compared with on the not cued trials.

Each infant's four trials were also grouped in the orthogonal way, in order to contrast behavior on the necessary versus the unnecessary trials collapsed across the cueing manipulation. Comparing performance when action A was necessary and unnecessary was not the focus of Study 2 and it is important to note that the toys were different in the two causal conditions; nevertheless, the fact that both necessary and unnecessary toys were included in Study 2 affords an opportunity to corroborate the results of Study 1. Accordingly, infants were assigned a score of 0, .5, or 1 based on the proportion of their two necessary trials on which they performed action A and they were assigned a similar score for their performance of A across their two unnecessary trials. The average score for performing A on the necessary trials was .71, while the average on the unnecessary trials was .58. Eight infants had higher scores for their necessary trials than for their unnecessary ones, while four showed the opposite pattern (the remaining infants' scores on the necessary and unnecessary trials were tied). This distribution is not significant by the sign test, binomial $p > .05$, although it is in the predicted direction. The same kind of analysis was also conducted based on the proportions of necessary and unnecessary trials on which infants performed A first (i.e., not after B). In this analysis, 13 infants had higher scores for their necessary than for their unnecessary trials, while 5 showed the opposite pattern; this distribution is significant by the sign test, binomial $p = .048$. Thus, over all four trials, although infants were not more likely to perform A in general on the necessary trials, they were more likely to perform A as their first action on those trials as compared with on the unnecessary ones.

Finally, using the McNemar test as described for Study 1, we also compared infants' behavior on the necessary and socially cued trial in particular against that on the unnecessary and not cued trial. These trials represent the two scenarios that infants probably encounter most frequently under natural circumstances. That is, when an action is integral to an effect, adult demonstrators most likely solicit an infant observer's attention, and when an action is not integral to an effect, they most likely do not. Our necessary and not cued trials and also our unnecessary and socially cued trials are combinations contrived for empirical purposes and probably are not experienced very often by infants in everyday life. As might be expected from the results already reported, the contrast between the two most natural trials yielded a robust effect. Six infants performed action A on the necessary and socially cued trial but not on the unnecessary and not cued one, while not a single infant did the converse, binomial $p = .016$. Likewise, more infants performed action A first on the necessary and socially cued trial but B first on the unnecessary and not cued trial ($n = 10$) than performed A first on the unnecessary and not cued trial but B first on the necessary and socially cued one ($n = 1$), binomial $p = .006$.

Looking behavior during the demonstrations. The numbers and percentages of infants who looked at the experimenter before she demonstrated action A and who looked at the demonstration itself are given for each type of trial in Table 3. From these data, it is clear that infants were no more likely to look at the experimenter on socially cued trials than on not cued trials. Indeed, on all types of trials, most infants did not look at the experimenter while she was talking before she performed action A! Instead, they were most often looking at the toy the experimenter had just been given, even when she was talking directly to them. Nevertheless, infants must have sensed somehow that the experimenter was talking to them on the socially cued trials, because they selectively imitated A on these trials and because they actually looked at the demonstration of A more often on these trials than on the not cued trials. As Table 3 shows, infants almost always looked at the demonstration of A when it was socially cued, but they did not watch the demonstration on nearly one third of the trials when it was not cued.

Given that some infants did not even see the experimenter carry out action A on the not cued trials, it is perhaps not surprising that A was imitated less frequently on those trials. To direct an infant's visual attention is surely one reason why adults provide social cues in the imitative context, and this function may have mediated the selective imitation we observed. However, controlling their gaze was not the only way in which the cueing manipulation affected infants' tendency to perform action A. On the not cued trials, of the instances where infants interacted with the toy but omitted action A entirely, the infant had nevertheless seen the demonstration of A in 11 of 15 cases. Similarly, of the instances where infants interacted with the toy but did not perform action A first, the infant had nevertheless seen the demonstration of A in 16 of 22 cases. Clearly, infants were not just failing to perform action A because they had not seen it on the not cued trials.

Table 3
Numbers of Infants Showing Certain Looking Behaviors for Each Cueing Condition and Type of Toy in Study 2

	Looked at E before demo of A		Looked at demo of A	
Condition	Yes	No	Yes	No
Socially cued and necessary	7	14	20	1
Not cued and necessary	8	13	14	7
Socially cued and unnecessary	3	16	19	0
Not cued and unnecessary	4	15	15	4

Because directing infants' attention to their actions is in fact one of the aims of adults providing social cues, trials on which infants did not observe action A should not necessarily be excluded (as generating artifact) from the data analyses—that would be undermining infants' sensitivity to this component of social cueing. On account of this reasoning, these trials were included in the comparisons already reported concerning the performance of A on the socially cued versus on the not cued trials. Nevertheless, to examine the role of cueing without this looking factor in the mix, we conducted the primary cued versus not cued analyses again, but this time including only those trials on which infants had actually seen A demonstrated. As described before, infants were given a score of 0, .5, or 1 according to the proportion of their socially cued trials on which they performed A, and they were also given an analogous score figured across their not cued trials; however, trials on which infants had not seen A demonstrated were not included in the computation of these scores. This new criterion meant that 2 infants who contributed to the original analyses could no longer be included, as they now had no viable not cued trials. However, most infants could still be given a meaningful not cued score; when a trial was eliminated for not seeing A demonstrated, a score could still be given based on the remaining trial of that type. The analysis of these scores including only trials on which infants had seen A demonstrated still shows a clear effect of the cueing manipulation. Nine infants had higher scores for performing A on the socially cued trials than on the not cued ones, while just two showed the reverse pattern (and 6 infants' scores were tied). This distribution is significant by the sign test, binomial $p = .033$. We also reran the corresponding analysis on the proportion of trials on which infants performed A first (i.e., not after B), again now using only the trials on which infants had seen A demonstrated. In this case, 13 infants had higher scores on the socially cued trials than on the not cued ones, while just 3 showed the opposite pattern (and 1 had a tied score); this distribution is also significant by the sign test, binomial $p = .011$. Thus, these repeat analyses indicate that even considering only those cases where infants clearly saw the demonstration of action A, they were still less apt to perform A and also less apt to perform it as their first action on the not cued trials than on the socially cued trials.

Discussion

The results of Study 2 first of all provide some support for the main finding of Study 1, that infants rely on their own understanding of physical reality to select actions to imitate. Although overall in Study 2 infants did not perform action A more frequently when it was physically necessary than when it was not, they were more likely to perform action A first on the necessary trials than on the unnecessary ones. This pattern of results suggests that infants saw, remembered, and were interested in exploring action A on the unnecessary trials, but did not construe A as integral to generating the effect. As can be seen from Table 2, most instances where infants performed A and B out of order occurred on the unnecessary trials, on which the effect would already have been experienced upon the performance of B. In these instances, infants presumably perceived from the demonstration that only B was critical to the effect, hence performed B and achieved the effect straight away, and then ''moved on'' to also explore the other action (A) they had observed. In contrast, on the necessary trials infants evidently perceived that A (as well as B) was critical to the effect and hence were more likely to perform the actions in the appropriate sequence. Thus, as with Study 1, the results of Study 2 indicate that infants rely on their emerging knowledge of barriers, movement, containment, etc. to select and prioritize actions to imitate.

Moreover, the results of Study 2 make it clear that infants also rely on social signals emitted by the model in their selection of actions to imitate. Infants were more likely to perform action A in general and also to perform it before action B on trials where A had been socially cued than on trials where it had not been cued. What is more, the toys and actions used on the socially cued and not cued trials were identical, and hence the difference in infants' tendency to perform A must have been due to sensitivity to the cueing manipulation; it could not have been due to any differences in the attractiveness of the toys, the difficulty of the actions, etc.

What aspect of the cueing manipulation was responsible for infants' selective imitation? An initial idea is that infants followed the experimenter's gaze to the wall on the not cued trials and then did not get their eyes back in time to see action A executed; hence they obviously could not imitate it. Infants do follow a social partner's gaze beginning at around 8–10 months of age (Butterworth & Grover, 1988; Carpenter, Nagell, & Tomasello, 1998; Corkum & Moore, 1998), and indeed some infants did look to the wall and therefore missed seeing action A on the not cued trials. However, even when we excluded these instances and analyzed only those trials where infants had clearly seen action A, infants were still more likely to perform A and to perform it first in the socially cued condition than in the not cued condition. They somehow knew that this action, observed in both cases, was important for them to duplicate in the socially cued condition but not in the not cued condition.

Although it is possible, it seems unlikely that 15-month-olds understood the actual words the experimenter uttered in the two cueing conditions and differentiated them on that basis. Nor was the experimenter's attempt to establish eye contact in the socially cued condition the critical factor, because most infants looked at the toy and not at the experimenter during this part of the trial. We surmise that as infants looked at the toy, they could see ''out of the corner of their eyes'' whether the experimenter was leaning in and looking toward them or whether she was sitting up straight and looking at the wall. From this body language, infants seemed to know that the experimenter was trying to engage them in the one case and not in the other. In other words, the experimenter's posture and proximity to the baby in the socially cued condition apparently signaled that she was talking to the infant and thereby marking the next action as something she meant for the infant to do.

That infants used the model's social behavior to guide their imitation is consistent with sensitivities shown in other learning contexts. Baldwin (1993) observed that at 19–20 months, infants use a speaker's direction-of-gaze to map novel words to the correct one of several possible referents, and Mumme and Fernald (2003) found that 12-month-olds used direction-of-gaze to link a speaker's emotion to the one object out of two that might have provoked it. Observing people's orientation to infer their attentional and intentional states seems to be a pervasive tactic for infants to pare down the options in a variety of perceptual and cognitive ambiguities. The results of Study 2 provide evidence that infants use this same tactic to help determine whether a particular action seen in the event stream is essential to producing an observed effect. In this way, infants' social skills may ''bootstrap'' their understanding of novel causal sequences, just as they bootstrap lexical acquisition and emotional mapping.

Thus, the results of Study 2 indicate that infants rely on both their own appraisal of an action's importance and the model's social signals to determine whether or not to imitate actions in an event sequence. Moreover, the results do not suggest that one of these factors influences infants' behavior any more than the other. If infants' understanding of physical reality was the overriding factor, then there should have been no difference between the cueing conditions collapsed across the necessary and unnecessary trials, and conversely, if infants' sensitivity to social signals was the overriding factor, then there should have been no difference between the causal conditions collapsed across the socially cued and not cued trials. In fact, there was a significant difference between the cueing conditions collapsed across causality and also a significant difference between the causal conditions collapsed across cueing, at least when the scores were based on whether action A was performed first (i.e., not after B). It seems that infants' own understanding and their sensitivity to other's signals both contribute to their tendency to imitate actions, in essentially an additive way. This interpretation is also supported by the fact that infants performed action A most often when it was both necessary *and* socially cued, and least often when it was neither necessary *nor* socially cued.

General Discussion

The purpose of the research reported here was to investigate how infants select actions from an event stream in their efforts to reproduce an observed effect. The results of Studies 1 and 2 indicate that infants' imitation of actions is constrained by their causal understanding and knowledge of the physical world. Infants in both studies were more likely to imitate the first of two actions modeled before an interesting effect if the first action was physically necessary for the effect to occur than if it was not. These results are consistent with prior findings showing that infants tend to imitate relevant actions more systematically than irrelevant ones (Bauer, 1992; Harnick, 1978). Moreover, the results here extend prior findings by indicating some of the bases infants use to determine an action's relevance. In Study 1, infants refrained from imitating actions directed toward places other than the object where the effect occurred, presumably in keeping with their belief that physical contact is required for causal influence. In both studies, infants also refrained from immediately imitating actions directed toward the effect site but such that they did not enable the effect; this exclusion was presumably in keeping with their knowledge of barriers, movement trajectories, and containment. It seems that the same knowledge of physical reality that prompts infants to show surprise at impossible events in preferential looking studies also allows them to recognize whether an action is essential to a goal in a demonstrated sequence, and accordingly leads them to include that action or not in their own attempts to produce the goal.

Infants' selection of actions to imitate is also influenced by the communicative behavior of the person initially performing the action. In Study 2, infants performed an action more often if the experimenter had spoken to them before modeling it than if she had not. From her interaction with them, infants evidently inferred that the experimenter's next action was meaningful and that she intended for them to do it also. Recent research has shown that infants rely on another's social signals and intentions in a variety of learning contexts (Baldwin & Moses, 1994; Carpenter, Akhtar et al., 1998; Mumme & Fernald, 2003; Repacholi, 1998), and our results further extend this sensitivity into the realm of interpreting action sequences for imitation.

The results of Studies 1 and 2 together make it clear that infants' imitation of goal-directed actions is a complex, multiply determined process. Although both the physical importance of an action and the model's social behavior affected whether infants imitated a particular action within a sequence, neither of these factors dominated the other. Infants are neither strict imitators nor are they pure emulators (cf., Want & Harris, 2002). Instead, infants seem to combine following the model's social cues with their own cognitive appraisals in order to filter and interpret event sequences (see Bauer & Kleinknecht, 2002, for a similar conclusion). An adaptive way for infants to effect this combination would be to weight the model's cues more heavily when they are uncertain about an action's relevance, but to rely mostly on their own judgment when they are more certain about it. Such a strategic approach is suggested by the fact that although both were socially cued, infants in Study 1 were somewhat more likely to imitate unnecessary actions than off-object actions, whose irrelevance may have been more obvious to them.

Finally, and more generally, the results and our interpretations suggest an interesting parallel between infants' processing of event streams and their approach to lexical acquisition. In their efforts to correctly pair both observed actions with effects and novel words with referents, infants appear to be broadly opportunistic. They look to a variety of social indicators, inherent biases, and preexisting knowledge bases to successfully manage these logically forbidding tasks. In the natural course of things, these various sources may often all support the same hypothesis; in these instances, infants can ''fast map'' causal actions to effects and new words to referents assuredly. The sources infants look to might not always concur, though, as when an adult's demonstration is interrupted, a cause is not colocated with its effect, or a speaker's gaze is not on what she is labeling. In these instances, the multiple cues infants rely on could serve to check and balance one another, so that a mapping is further explored, made more tentatively, or perhaps even not made at all. Thus, infants' reliance on multiple sources of information to solve correspondence problems may play a protective role. For imitating actions in the stream of events, it helps them to do just the right thing.

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