Developmental Psychology
2008, Vol. 44, No. 1, 275–285

0012-1649/08/$12.00 DOI: 10.1037/0012-1649.44.1.275

Prior Experiences and Perceived Efficacy Influence 3-Year-Olds' Imitation

Rebecca A. Williamson and Andrew N. Meltzoff
University of Washington

Ellen M. Markman
Stanford University

Children are selective and flexible imitators. They combine their own prior experiences and the perceived causal efficacy of the model to determine whether and what to imitate. In Experiment 1, children were randomly assigned to have either a difficult or an easy experience achieving a goal. They then saw an adult use novel means to achieve the goal. Children with a difficult prior experience were more likely to imitate the adult's precise means. Experiment 2 showed further selectivity—children preferentially imitated causally efficacious versus nonefficacious acts. In Experiment 3, even after an easy prior experience led children to think their own means would be effective, they still encoded the novel means performed by the model. When a subsequent manipulation rendered the children's means ineffective, children recalled and imitated the model's means. The research shows that children integrate information from their own prior interventions and their observations of others to guide their imitation.

Keywords: imitation, goals, intention, prior experience, social cognition

Children are remarkably adept at imitating. Not only do they copy the overall goal or outcome of a demonstration, they can also imitate the precise means a model uses to attain that goal. The capacity to frequently and consistently imitate models' means—the manner in which models move and the way they achieve a goal—may be unique to humans. Several experiments have now shown that children are more likely than nonhuman primates to imitate a model's exact actions or means (e.g., Horner & Whiten, 2005; Tennie, Call, & Tomasello, 2006; Whiten, Custance, Gomez, Teixidor, & Bard, 1996; Whiten, Horner, Litchfield, & Marshall-Pescini, 2004). On one hand, such hyperimitation can sometimes be counterproductive: For example, preschool-age children are more likely than chimpanzees to imitate actions that are not necessary for completing a task (Horner & Whiten, 2005; Whiten et al., 1996). On the other hand, the underlying propensity to imitate a model's means (not just the endpoint achieved) allows children to learn subtle strategies and techniques, such as the specific way to most effectively manipulate tools (e.g., Meltzoff, 2007b; Nagell, Olguin, & Tomasello, 1993). Two general questions arise from the current literature on the development of imitation: (a) Are children intelligent or rigid imitators—compulsive copiers or flexible learners? (b) What regulates whether children choose to imitate the precise means they witness?

Although children can imitate the means they see others use, they do not slavishly duplicate them. Children use their understanding of the overall goal of a task to guide their imitation of both means and ends (e.g., Bekkering, Wohlschläger, & Gattis, 2000; Carpenter, Call, & Tomasello, 2005; Gleissner, Meltzoff, & Bekkering, 2000; Williamson & Markman, 2006). For example, Bekkering et al. had 4- to 5-year-olds imitate a model reaching to a goal (e.g., touching dots on a table). The model used distinctive means in completing this goal, sometimes reaching across the body to the dot and sometimes using the hand on the same side of the body. The preschoolers successfully reached for the same physical dot as the model; however, they often failed to imitate the model's precise means (i.e., the precise type of reach used). In contrast, when they saw only the model's different reaches without the dots present—when there was no external goal to achieve (other than the motor act itself)—the children were significantly more likely to reproduce the same arm movement as the model. This same effect was replicated and extended when the model demonstrated reaching to an invisible body part, such as one's own ear: If the goal was to reach for the ear, children successfully imitated this endpoint but did not follow the adult's precise means. However, if the act was to reach to the place in space near the ear—that is, if it was a body act with no clear object at its endpoint—children imitated more exactly, including the precise type of reach used (Gleissner et al., 2000).

These results suggest that when a demonstration does not have a clear goal, children are more likely to imitate the precise actions the adult used. Similarly, results from Carpenter, Call, and Tomasello (2002) suggest that children are more likely to imitate the adult's precise acts when the goal is not made clear at the start of a difficult demonstration. In this study, 2-year-olds saw an experimenter demonstrate a multistep series of actions to open a box. When the goal was made explicit at the beginning of the trial (e.g.,

Rebecca A. Williamson and Andrew N. Meltzoff, Institute for Learning and Brain Sciences, University of Washington; Ellen M. Markman, Department of Psychology, Stanford University.

Portions of this work were presented at the meeting of the Cognitive Development Society, October 2005, San Diego, California, and the meeting of the Society for Research in Child Development, March–April 2007, Boston, and were reported in Rebecca A. Williamson's dissertation. We gratefully acknowledge funding from National Institutes of Health Grant HD-22514, National Science Foundation Grant SBE-0354453, and the James S. McDonnell Foundation Causal Learning Network. We thank Alison Gopnik, Betty Repacholi, and Laura Schulz for useful comments on a draft of this article and are grateful to the participating children and parents from Bing Nursery School and the Seattle area.

Correspondence concerning this article should be addressed to Rebecca A. Williamson, Institute for Learning and Brain Sciences, Box 357988, University of Washington, Seattle, WA 98195. E-mail: rawillia@u.washington.edu

the experimenter showed the children that the box could open before demonstrating how to do so), more children completed the overall goal of the demonstration; however, they were less likely to reproduce the exact style the experimenter used to complete the steps of the task (e.g., the exact twisting movement used to remove a pin). Older results of Harnick (1978) and Sibulkin and Uzgiris (1978) are compatible with these findings, showing that children between 14 months and 4 years were more likely to imitate a model's exact action when a task involved many steps that might make the goal difficult to interpret versus when the solution was obvious.

Children may not even have to see the overall goal completed to understand it and use their own means. In Meltzoff's (1995) reenactment paradigm, 18-month-olds saw an adult repeatedly use unsuccessful means for pulling an object apart (the adult's hands slipped off the sides, and the object remained untransformed). The study revealed two interesting points. First, infants extracted the goal from the unsuccessful attempts, inasmuch as they subsequently reenacted the goal of the act. Second, children used their own means to achieve the goal successfully; instead of using the model's distinctive two-finger-plus-thumb grip (which slipped off the object; see Meltzoff, 1995, Figure 2), the children often used other approaches to achieve the same end, such as wrapping their fingers around the side to pull the toy apart (Meltzoff, 1995, Footnote 4; see also Meltzoff, 2007b, Experiment 2).

Several hypotheses have been offered to account for why children show higher levels of imitating a model's precise actions when the goal of a demonstration is not clear. One proposal is that children conceptualize others' behaviors hierarchically and that overarching goals are more dominant in this hierarchy (Bekkering et al., 2000; Gattis, Bekkering, & Wohlschläger, 2002; Wohlschläger, Gattis, & Bekkering, 2003). The demonstration of a clear goal is said to restrict children's imitation of the means because children have information-processing limits and respond to items that are higher in the hierarchy (Bekkering et al., 2000). A different suggestion is that when the overall goal is not clear children may assume the actions themselves are the model's goal and imitate them (Carpenter et al., 2005). Finally, when children are unsure of the goal of the task, they may conservatively imitate a model's precise means and thereby have a better chance of attaining the goal (Williamson & Markman, 2006). These positions are not mutually exclusive—several could affect children's imitation, perhaps even at the same time.

Even when a task has a clear goal, the deliberateness of the adult's actions has been shown to influence the degree to which children imitate his or her means. Children are more likely to imitate when models mark their means as purposeful. In an experiment by Carpenter, Akhtar, and Tomasello (1998), 14- to 18-month-old children saw an adult perform two actions on an object to produce an outcome. The adult used emotional and verbal cues to mark one of the actions as accidental (e.g., "Woops!") and one as purposeful (e.g., "There!"). The children were more likely to imitate means marked as purposeful. In addition to such verbal cues, the behaviors used by the adult model may also carry information that particular means are purposeful. Brugger, Lariviere, Mumme, and Bushnell (2007) suggested that 14- to 16-month-old infants are more likely to imitate demonstrated means when the adult's body language (e.g., leaning forward and looking) is directed at the toy. Mothers have also been shown to naturally use exaggerated movements and repetition in their demonstrations to children (Brand, Baldwin, & Ashburn, 2002)—a kind of "motionese" analogous to verbal "motherese" used with infants (e.g., Fernald & Simon, 1984; Fernald et al., 1989; Kuhl et al., 1997).

Building on this idea, Csibra and Gergely (2006) suggested that adults use behaviors such as directed eye gaze and distinctive voices and actions when establishing a "pedagogical" exchange. These cues may be especially powerful in leading children to be attentive to learn new information. According to Csibra and Gergely, when these cues are present children try to discover what the adult is teaching them. Thus, in such a pedagogical setting children may focus on actions that are strikingly different from behaviors that might be expected. For example, in Meltzoff's (1988) study, 14-month-old children imitated an adult's novel means of bending at the waist to turn on a light with his or her head. The children might have shown high levels of imitation because the engaged adult (by using directed eye gaze and taking turns with the child) seemed to be showing them what to do. A still richer interpretation of such imitation is that the children interpreted the scene with reference to a principle of rational action (Gergely, Bekkering, & Király, 2002), which led them to think, for example, "There is no rational/instrumental reason why he is doing this odd behavior, so it must be something he wants to teach me."

In addition to factors indicating that the precise acts are deliberately directed to the infant for his or her use, an adult's failures can be a cue to children. By observing the failures of others, infants can infer that alternate means are important for completing the task. In a study by Nielsen (2006), for example, 12-month-olds saw a model open a box. The model always used a tool to complete the task, but sometimes the model first struggled to open the box with his hand before resorting to the tool. Children were more likely to use the tool after seeing the model fail with his hands than when the model was initially successful with the tool. Thus, giving children evidence that only specific, novel means are effective for a task and that the ordinary ones fail may make them more likely to imitate those specific means (see also Want & Harris, 2001, 2002, for related results with older children).

In this previous work, children received evidence through observation that particular means were causally efficacious. Children observed a variety of different means, only some of which were effective, and they chose whether to adopt these means. There is, however, another channel by which children can learn about the effectiveness of means, and that is through their own acts —their own prior experience with a task. The current experiments examine whether children combine their own prior experience with what they observe others do to guide their imitation. Three-year-old children were given problems to solve, such as opening a drawer to retrieve a toy. We tested 3-year-olds both because children of this age can complete relatively sophisticated means–ends tasks and because this age group is often used in the literature on comparative imitation. If children have a difficult time completing a goal using their own means, they may be more open to adopting and imitating another's causally efficacious actions. In contrast, if children's own means are efficient for completing the task, they may be less likely to adopt a model's means. Thus, children's prior knowledge about their own proficiency on a task may be an important factor influencing whether they imitate the means used to complete a clear goal.

Experiment 1

This experiment tested whether children's own hands-on experience with a task influenced whether they imitated the precise means a model used to achieve the same goal. Three-year-olds were given problems to solve, such as opening a drawer to retrieve a toy. The experimental manipulation consisted of surreptitiously varying how difficult it was for the children to complete the goal on their initial experience with the task: Half of the children were randomly assigned to a group that could achieve the goal easily (the easy-experience group), and the other half were assigned to a group that had difficulties (the difficult-experience group). After this initial experience, children saw a model use a distinctive means that allowed her to easily achieve the goal. We predicted that children would imitate the adult's means more often when their own prior experience indicated that it was difficult for them to achieve the goal, thus integrating their own prior experience with their observations of the acts of others.

Method

Participants

The participants in this experiment were 24 three-year-old children (M = 3.3 years old, range = 3.0–3.9 years old). The children were from a university preschool, with approximately equal numbers of boys and girls. Exact demographic information was not collected, but the school enrolled children primarily from White, middle-class families and also included children of African American, Hispanic, Asian, and Native American parents. Children were tested without regard for racial or ethnic background as long as parents gave consent.

Materials

Each child was seen individually in a lab room at the preschool, and the sessions were videotaped for subsequent coding. Two sets of objects served as stimuli, each of which contained three exemplars. One set of objects consisted of three stacked plastic drawers, commonly used for storing pencils or other small office supplies (see Figure 1). The drawers were vertically stacked and attached to one another to make one object (16 × 17.5 × 20.5 cm). Each drawer contained a different small toy (approximately 5 × 5 cm), such as a plastic fish. The second set of objects consisted of three toy cars (each approximately 5 × 8 × 5 cm), each situated in a lane made from foam board (5.5 × 40 cm).

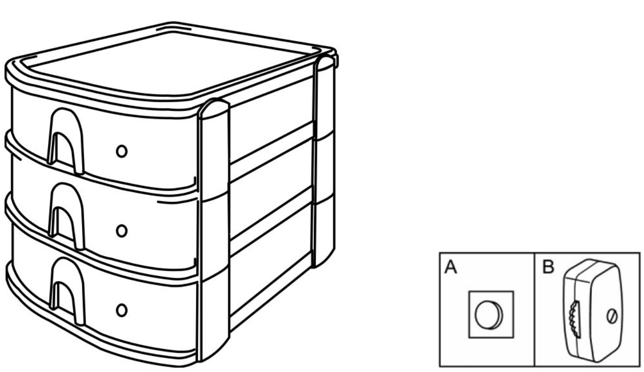

Figure 1. An example of the drawer stimuli used for all experiments, fitted with a small button (A) on each drawer face. For half of the trials in Experiments 2 and 3, instead of the small button, a wheeled switch (B) was attached to the side of each drawer.

The top drawer and first car (the car farthest to the experimenter's left) were altered so that the experimenter could vary the ease with which they could be moved. For the drawer, putty was inserted unobtrusively in the back of the drawer to make it difficult to open. Without this, the drawer slid open easily. Each of the three cars had a line attached to it. However, the line from the first car was attached to a thin filament wound around a hidden fishing reel. When enabled, this reel provided tension to the line, making the car difficult to move down the track; with the reel toggle flipped to the other position, the line ran out with no resistance.

Procedure

According to a between-subjects design, children were randomly assigned to have either an easy or a difficult initial experience completing a goal. Each child received two trials, one using each stimulus. Which stimulus was presented first was counterbalanced across the children.

Warm-up. The experimenter introduced the task to the children by telling them they would take turns playing with toys, explaining either that they would open each closed drawer to retrieve a toy or that they would drive each car to the end of the lane.

Prior experience. The children were given an initial experience with the task. The experimenter told them, "Go ahead; it's your turn first," and gestured to the first drawer or car. The children then opened the first drawer and retrieved a hidden toy or drove the first car down the lane. This initial experience with each apparatus was designed to set the children's expectations for how difficult the task was to complete. Thus, in the difficult-experience group, the drawer was jammed so it was hard to open, and the car was restrained so it was hard to move down the lane. In the easy-experience group, the drawer and car were free and easy to move.

Demonstration period. In the second phase of each trial, the experimenter drew the child's attention by saying, "It's my turn now; watch," and then easily completed the task using a distinctive means (the target act). For the car stimulus, she pushed the second car down the lane using only her extended index and middle fingers, and the car moved easily along the track. For the drawer stimulus, the experimenter pushed a button on the face of the second drawer and then pulled it open smoothly and retrieved a toy (in reality, the button was nonfunctional). On average, the car demonstration took 6.0 s (SD = 1.7), and the drawer demonstration took 4.3 s (SD = .8).

Response period. The children were told, "Now it's your turn again," and were allowed to act on the third member of the set, which was always unimpeded. Thus, the children either opened the third drawer to retrieve a hidden toy or drove the last car to the end of the lane.

Scoring and Dependent Measures

Duration of effort. The length of time it took children to complete the goal during the prior experience phase of the trial was measured from the video via a time stamp on the recording. Timing began for the drawer apparatus when the children touched the handle of the first drawer and ended when the first drawer opened—that is, when the face of the drawer separated from its frame. For the cars, the timing began when the child touched the car and ended when the car touched the end of the lane. One drawer trial could not be coded because the video image was blocked.

Verbal comments. All of the children's comments in the prior experience phase were transcribed from the video to assess whether they experienced difficulty with the task. Two independent coders who did not know which group the children were in indicated whether each transcribed comment related to the children's experience with the task (e.g., "It's hard") or whether it was irrelevant (e.g., "Now?"). Of those comments that related to the children's experience, the coders rated whether the comment indicated that the task was difficult or easy to complete. There was 100% agreement between the coders on both measures.

Imitation score (number of target acts produced). A scorer, who did not know the hypothesis of the study or which group the children were assigned to, made a yes/no judgment of whether the children reproduced the target act from video. For the drawer stimulus, children were credited with a "yes" if they pressed or otherwise intentionally manipulated one of the buttons on the face of the drawers. For the cars, the children were credited with a "yes" if they pushed the top of the car with the extended index or middle finger (or both). The primary data were derived from whether the children produced the target acts during the response period (i.e., from the time the second drawer closed until the third drawer first opened, $M = 3.6$ s, $SD = 1.8$, or from the time the experimenter released the second car until the third car reached the end of its lane, $M = 3.4$ s, $SD = 1.1$). The scorer also recorded whether the target acts were produced during the prior experience phase of the trials. A second scorer, who also did not know the experimental hypotheses or which group the children were in, coded a randomly selected 25% of the videotaped trials for the production of the target act. Scoring agreement was high (Cohen's $\kappa = .86$).

Results and Discussion

A manipulation check confirmed that, as planned, during the prior experience phase of the trial the children in the difficult-experience group had a more difficult time completing the goal than those in the easy-experience group. Children took longer to achieve the goal in the former ($M = 9.3$ s, $SD = 4.0$) than in the latter group ($M = 2.2$ s, $SD = 1.3$), $t(22) = 5.93$, $p < .001$. This significant effect was obtained for both the drawer stimulus (difficult experience, $M = 8.6$ s, $SD = 5.0$; easy experience, $M = 1.7$ s, $SD = 1.6$) and the car stimulus (difficult experience, $M = 11.0$ s, $SD = 6.4$; easy experience, $M = 2.6$ s, $SD = 1.9$) taken individually (both $ps < .01$).

Analyses of the verbal comments also indicated that the difficulty of the task was different between the two experimental groups. Fully 67% of all of the children's verbal comments made during the prior experience phase related to their experience with the task. All of these task-related comments were about difficulty (e.g., "It's hard" or "It's stuck"). Significantly more children made these comments in the difficult-experience group (7 of 12 children) than in the easy-experience group (1 of 12), $\chi^2(1, N = 24) = 6.75$, $p < .01$. Thus, both measures of task difficulty, children's duration of effort and their verbal responses, indicated that the experimental manipulation worked as intended.

Preliminary analyses of the number of target acts produced revealed no significant effects of sex, age, trial number, type of stimulus (drawers vs. cars), or stimulus order. The data were therefore collapsed across these factors. Children received a score from 0 to 2 for the number of trials on which they produced a target act during the response period. This was converted to a percentage of trials on which the children produced the target act during the response period (either 0%, 50%, or 100%). A significant difference was observed in the percentage of trials on which the target act was produced between the two experimental groups (see Figure 2), with significantly more target acts produced in the difficult-experience group ($M = 54\%$, $SD = 50\%$) than in the easy-experience group ($M = 17\%$, $SD = 25\%$), $t(22) = 2.34$, $p < .05$.

Only a few children produced target acts during the prior experience phase of the trial through baseline play (difficult-experience group, $M = 8\%$ of the trials, $SD = 19\%$; easy-experience group, $M = 13\%$, $SD = 23\%$). A paired *t* test showed that the children in the difficult-experience group were significantly more likely to produce the target acts during the response period than in this prior experience phase of the trial (before they had seen the adult's demonstration), $t(11) = 2.93$, $p = .01$. This supports the idea that the children in the difficult-experience group were imitating the experimenter's demonstration. Imitation was not observed in the easy-experience group, inasmuch as these children were no more likely to produce the target acts during the response period than in the prior experience phase ($p = .72$).

The significant difference in the number of target acts produced as a function of experimental treatment (difficult- vs. easy-experience groups) supports the hypothesis that children selectively imitate an adult's acts depending on their own prior experiences with the difficulty of a task. When presented with a task with which they had prior difficulty, the children were significantly more likely to imitate the model's precise acts in their later attempts. This suggests that they were integrating information from their own hands-on prior experiences with the information gleaned through observations of the acts of others to govern their imitative acts.

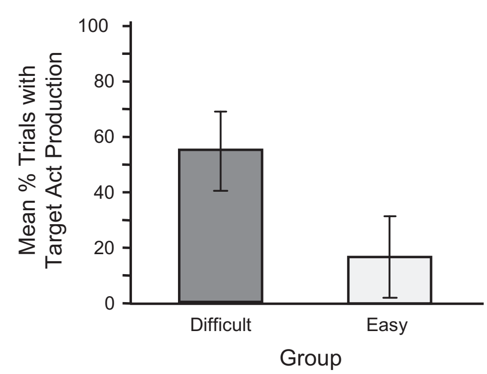

Figure 2. Experiment 1: Mean percentage of trials on which the target act was produced (plus or minus standard error) when the children had an easy or difficult initial experience.

Experiment 2

Experiment 1 suggests that children are more likely to imitate another person's means when they find that their own means are not ideal for completing a task. Harnick (1978) reported a related finding by showing that young children were more likely to imitate an adult's precise mannerisms and unusual behaviors when the model demonstrated a challenging task that involved several steps versus an easier version of the task. Many of the actions those children imitated, however, seemed irrelevant to completing the goal (e.g., clapping to work a ball through a maze.) Harnick's results might suggest that when children are presented with a difficult task, they do not evaluate the specific means used by the model but rather imitate all they can from a demonstration—a kind of "copy all" procedure. Alternately, a difficult task may prompt children to scrutinize the adult's demonstration for causally efficacious clues (Gopnik & Shulz, 2007; Schulz, Hooppell, & Jenkins, in press) about how to solve the problem. Experiment 2 was designed to test whether the difficult experience in our procedure prompted selective imitation: Would children preferentially imitate the potentially causally efficacious components, or would they perform a blanket imitation of everything the model did?

After a difficult initial experience with a task (as per Experiment 1), the children were randomly assigned to one of three groups. For all groups, the model used distinctive means (e.g., pressing a button) before trying to open a drawer or box to retrieve a toy. However, by experimental design, this same means led to success (e.g., opening the drawer) in one group (model successful) and was observed to be ineffective for the other groups. For one ineffective group (Model Unsuccessful 1), the model simply could not open the drawer or box. To ensure that low levels of imitation would not be due to the child not getting to play with the toy, in the Model Unsuccessful 2 group the model brought out a second, identical toy for the child from a different location when the drawer or box could not be opened. In all other respects, the two model-unsuccessful groups were identical.

If children enter a copy-all mode after a difficult experience, we would expect similar reproduction of the means regardless of whether the adult's means were efficacious. The children should be indiscriminate imitators regardless of the adult's perceived success. However, if a difficult hands-on experience prompts children to imitate but to do so selectively, they should preferentially imitate experts and the causally efficacious means that lead to success.

Method

Participants

The participants were 36-month-old children ($N = 36$, $M = 3.0$ years old, range = 2.9–3.1 years old). There were 19 girls. Children were recruited by telephone through the university's child participant list. The racial make-up of the sample, according to parental report, was 67% White, 8% Asian, 14% mixed race, and 11% other or unknown, with 6% reporting Hispanic ethnicity. Direct measures of socioeconomic status were not obtained, but the population was generally middle to upper middle class. Three additional children were tested, but their data were excluded because of an experimenter error (2 children) and an interrupted testing session (1 child).

Materials

One stimulus was the three stacked plastic drawers from Experiment 1. The second was a set of three plastic boxes with hinged lids (6.5 × 16.5 × 20 cm), which replaced the cars used in Experiment 1. The boxes allowed for a two-step act that was more directly comparable to the means used in the drawers set. One of six small toys (approximately 4 × 3 cm), such as a plastic pig or dinosaur, was placed in each drawer or box during the procedure. To increase the generalizability of the effect, one of two potentially functional parts was attached to each stimuli set. The target act used with the drawers was either pushing a small button with the index finger or turning a wheeled switch with the thumb (see Figure 1). The distinctive act used with the boxes was either swiping the lip of a plastic latch with the index finger or pressing a large button with the thumb.

The first drawer and the first box in each set had putty inserted unobtrusively, so that it was always difficult for the children to open. The second drawer and the second box were modified to incorporate a hidden locking mechanism, so that they could be made impossible to open. When the lock was engaged, the experimenter could realistically struggle with the containers and not open them. When it was disengaged, the experimenter could easily open the containers. The third drawer or box in each set was free to open.

Procedure

The test took place in a laboratory setting, and the children's parents either sat in a corner of the testing room or observed a live video feed in a nearby room. Children were randomly assigned to one of three independent groups: model successful, model unsuccessful 1, or model unsuccessful 2. By experimental design, the children in all three groups had a difficult experience opening the first drawer or box to find the small toy. At that point, their experiences diverged. The model-successful group followed the same general procedure as the difficult-experience group of Experiment 1. In both model-unsuccessful groups, the experimenter tried to but did not open the container during the demonstration phase of each trial. Each child received two trials, with stimulus order (drawer or box) counterbalanced across children. Each potentially functional part (e.g., button or switch for the drawers) was used for half of the trials with that stimulus, again counterbalanced for order.

Warm-up. The children in all groups first participated in an origami task with the experimenter. They then joined the experimenter in placing a different toy into each preopened drawer or box before each trial started. The same toy was always placed in the same drawer or box. After all three drawers or boxes were closed, the children were told they would take turns opening the drawers or boxes.

Prior experience. In all groups, the first drawer and box were fixed with a hidden brace of putty, so that it was difficult but always possible for the children to open them. On average, it took the children 7.3 s ($SD = 8.5$) to open the drawer and 8.1 s ($SD = 5.2$) to open the box, which were comparable to the times in the difficult-experience condition of Experiment 1.

Demonstration period. After the child's experience with the first drawer or box, the experimenter demonstrated a distinctive means (the target act) on the second drawer or box in the set. For example, she pressed the small button on the drawer face with her index finger. In the model-successful group, the experimenter then easily opened the container and gave the child the toy to play with. In both model-unsuccessful groups, the container was rigged so that it could not be opened. After performing the target act, the adult visibly pulled the handle to open the drawer or box but could not do so. To make the interaction naturalistic for the children, verbal comments accompanied all of these acts. This script avoided strongly negative words, such as *no.* Instead, the model only said, "It's stuck," on the unsuccessful attempt with the first stimulus and, "I can't open this one either," on the second stimulus.

In the model unsuccessful 1 group, after the experimenter's attempt, the children were told, "Well, that's OK," and the procedure continued to the response period. In the Model Unsuccessful 2 group, after the unsuccessful attempt, the experimenter said, "That's OK, I have another one," and retrieved a toy identical to the one in the drawer or box from below the table. This model unsuccessful 2 group provided a check on whether low levels of target production in the model unsuccessful 1 group might have been due to the children not getting to play with the toy. As in the model-successful group, the children were allowed to play with the toy for as long as they liked. Then the toy was returned to the experimenter and moved out of sight before the trial continued. The average length of the demonstrated act (from the time the first drawer or box closed until the model opened the second drawer or box or until the adult's hand movement was stopped by the lock) was 5.1 s ($SD = 1.2$) for the drawers and 5.4 s ($SD = 1.6$) for the boxes.

Response period. The children were told that it was their turn again and were given a chance to open the third drawer or box to retrieve the toy inside. In all cases, this drawer or box could easily be opened.

Scoring and Dependent Measures

The children's behavior was scored from video by a coder who did not know the hypothesis of the study or the children's experimental group. The dependent measure was a yes/no evaluation of whether the children produced the target act during the response period, from the time the second container closed until the children opened the drawer ($M = 5.4$ s, $SD = 5.4$) or box ($M = 4.1$ s, $SD = 2.5$). The operational definitions of the target acts were as follows. To be credited with a "yes," the children had to be judged to press or intentionally manipulate the buttons, manipulate the base or wheel of the switch, or swipe or rub the curved top of the latch. For the purposes of data analysis, children received a score of 0%, 50%, or 100% for the percentage of trials on which they produced the target act during the response period. For completeness, as in Experiment 1, the scorers also recorded target acts produced during the prior experience phase of the trial. A second scorer, who did not know the hypothesis of the study or the children's experimental group, coded a randomly chosen quarter of the trials. Agreement was 100%.

Results and Discussion

Preliminary analyses of the number of target acts produced revealed no significant effects of sex, trial number, type of stimulus (drawers vs. boxes), stimulus order, or which nonfunctional part was on the stimulus. The data were therefore collapsed across these factors.

A repeated measures analysis of variance (ANOVA) was conducted with the mean target act score as the dependent measure (see Table 1). Group (3: model successful, model unsuccessful 1, model unsuccessful 2) was the between-subjects factor, and trial phase (2: prior experience and response period) was the within-subject factor. There was a significant main effect of trial phase, $F(2, 33) = 13.54$, $p < .01$, suggesting that children were more likely to produce the target acts after they had seen the experimenter's demonstration than they were during spontaneous play in the prior experience phase of the trial. There was also a significant main effect of group, $F(2, 33) = 4.44$, $p < .05$, suggesting that the perceived efficacy of the model played a role in children's selective imitation. There was also a significant interaction between trial phase and group, $F(2, 33) = 5.29$, $p = .01$. This interaction clarifies the main effects. A follow-up one-way ANOVA for the response period alone showed a significant effect of group on children's target act production, $F(2, 35) = 6.03$, $p < .01$. A Newman–Keuls test revealed that children were significantly more likely to reproduce the target act in the model-successful group than in either the model unsuccessful 1 or the model unsuccessful 2 groups ($p < .05$), with no significant difference between the latter two groups. This shows that children selectively reproduced the model's distinctive acts when they were efficacious in completing the goal but not when they appeared to be ineffective.

During the prior experience phase (spontaneous play) before the adult's demonstration, there was, as expected, no significant difference in target act production as a function of group ($p = .77$). The children in all groups rarely produced the target acts during spontaneous play. Paired t tests showed that the children in the model-successful group were more likely to produce the target acts during the response period than they were during the prior experience (spontaneous play) phase, $t(11) = 4.06$, $p < .01$. Conversely, as predicted, there was no significant difference in target acts as a function of the study phase for either of the model-unsuccessful groups ($p > .16$ for each). These analyses provide further evidence for selective imitation of the target acts in the model-successful group.

Taken as a whole, these results show that after a difficult experience, the children in this experiment did not use a copy-all procedure and indiscriminately imitate the adult's acts. Children in all groups observed the same distinctive target acts executed by the adult, but sometimes these acts led to success and sometimes not. Children were significantly more likely to

Table 1
Experiment 2: Mean Percentage of Trials With Target Act Production

	Trial phase (%)	
Group	Prior experience	Response period
Model Successful	4 (4)	54 (11)
Model Unsuccessful 1	8 (6)	17 (9)
Model Unsuccessful 2	4 (4)	13 (7)

Note. Standard errors are in parentheses.

reproduce the model's means when these behaviors were seen as causally efficacious in achieving the goal (the model-successful group) than when they were not. This held regardless of whether the child received the toy to play with (model unsuccessful 2) or not (model unsuccessful 1).

Experiment 3

Experiment 1 showed that if children had an initial experience with a task that indicated that their own means worked well, they were not likely to imitate the adult's distinctive means. Did children fail to encode the adult's novel acts when their own prior means were successful? Experiment 3 addresses whether children watch and learn from the adult's demonstration under these circumstances. Children in the experimental group were given an initial, easy experience with a task (which in Experiment 1 led to lack of imitation of the adult's means). After the model's successful demonstration, the objects were surreptitiously changed, so that it was now impossible for the children to reach the goal. If the children encoded the adult's means, they might recall and imitate them when their own means were no longer effective. This ability to recall what an expert demonstrated would be useful in real world problem solving—even if children initially do not use the expert's technique, it would be useful to remember if their own actions fail.

Two control groups were included. A no-demonstration control group was used to assess the baseline probability that children would spontaneously produce the target act when their own acts were unsuccessful. Additionally, to further extend the findings of Experiment 2, we used a model-unsuccessful group. If the children discount the model's actions because of the perceived failure, we would expect to see low levels of imitation of this model even when children's preferred means are wholly unsuccessful. In sum, after discovering that their own means are now unsuccessful, children may be significantly more likely to imitate from memory a model who had been successful in reaching the goal rather than one who had not been successful.

Method

Participants

A new group of 36-month-old children ($N = 36$, $M = 3.0$ years old, range = 2.9–3.2 years old) was recruited from the university child participant list. There were 19 girls and 17 boys. The racial make-up of the sample, according to parental report, was 72% White, 3% African American, 6% Asian, 3% Hawaiian/Pacific Islander, 14% mixed race, and 3% other or unknown, with 6% reporting Hispanic ethnicity. Direct measures of socioeconomic status were not obtained, but the population was generally middle to upper middle class. Four additional children were tested but excluded from the final sample because of experimental error (1 child) and equipment failures (3 children).

Materials

As in Experiment 2, three plastic drawers and three plastic boxes with hinged lids were each fitted with one of two potentially functional parts, and each had a small toy that fitted inside. The last drawer and box in each set were modified to incorporate a hidden magnetic locking mechanism that the experimenter could surreptitiously unlock and lock via a hidden mechanism. When locked, these containers could not be opened. In the model-unsuccessful group, the second drawer or box was also locked, as in Experiment 2.

Procedure

The test took place in a laboratory setting, and the children's parents either sat in a corner of the testing room or observed a live video feed in a nearby room. The children were assigned to one of three independent groups: model successful, model unsuccessful, or a no-demonstration baseline control. Each child received two trials. Which stimulus set came first was counterbalanced across children, as was the use of each potentially functional part. In all groups, the children initially had an easy prior experience with the task before seeing the adult demonstration, and for all groups the final phase of the task was surreptitiously manipulated so that it was impossible to reach the goal until the experimenter unlocked the mechanism.

Warm-up. The children in all groups first participated in an origami task. They then joined the experimenter in placing a toy into each preopened drawer or box before each trial started.

Prior experience. The children were given an easy experience with the task. Similar to the easy-experience condition of Experiment 1, on average, it took the children 1.1 s ($SD = 1.3$) to open the drawer from the time they first touched it and 0.5 s ($SD = 0.6$) to open the box.

Demonstration period. The adult's demonstration varied across the groups. For the model-successful group, the experimenter performed a distinctive means (the target act) before easily completing the task on the second drawer or box. For example, the model pressed the button, easily opened the drawer, and retrieved the toy that was inside. For the model-unsuccessful group, the experimenter performed the distinctive means but could not complete the task. For example, she pressed the button, pulled the drawer, and, when it did not open, said, "Oh, it's stuck." For the no-demonstration baseline control group, the adult did not perform the target act or complete the overall goal of opening the container. For this control group, the experimenter said, "This is the drawer I get to open," and then drew attention to the drawer by moving her hand back and forth in front of the face of the drawer or the top of the box. In both the model-unsuccessful and the no-demonstration groups, after trying to open or drawing attention to the drawer or box, the adult told the children that she was going to wait to take her turn at opening the container and let the children open the last box or drawer. The adult demonstration phase took 4.6 s ($SD = 1.1$) for the drawers and 4.9 s ($SD = .9$) for the boxes.

Response period. For all groups, the third container was fixed with the magnetic mechanism and could not be opened until the experimenter secretly disengaged it. For the response period, the children were given the containers for 10 s, as recorded by a remote timer. If the children produced the target act (e.g., pressed the button on the face of the drawer), the experimenter disengaged the lock, and the container could be opened. If the children commented on being unable to open the drawer, the experimenter made mildly encouraging comments, such as, "Go ahead, it's your turn."

Scoring and Dependent Measures

The children's behavior was scored from the video records by a coder who did not know the hypothesis of the experiment or the children's experimental group. The chief dependent measure was a yes/no evaluation of whether the children produced the target act during the response period. For the purposes of data analysis, each child received a score of 0%, 50%, or 100% according to the percentage of trials on which they produced the target act during the response period, according to the operational definitions established for Experiment 2. The number of target acts children produced during the prior experience phase of the trials was also recorded. A second scorer, who also did not know the hypothesis of the study or the children's group, scored a randomly chosen quarter of the data. Agreement was 100%.

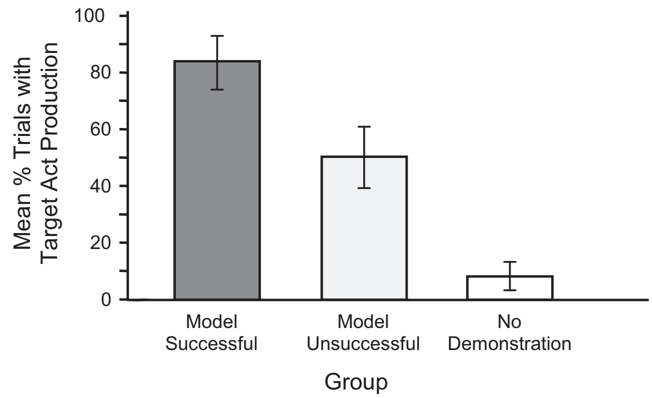

Figure 3. Experiment 3: Mean percentage of trials on which the target act was produced (plus or minus standard error) in each of the experimental groups.

Results and Discussion

Preliminary analyses of the number of target acts produced revealed no significant effects of sex, trial number, type of stimulus (drawers vs. boxes), stimulus order, or which nonfunctional part was on the stimulus. The data were therefore collapsed across these variables. Spontaneous rates of target act production were low during the prior experience play with the objects before the adult's demonstration. Across all 36 participants, a target act was produced on only a single trial during the prior experience phase. Additionally, during the response period of the no-demonstration group, 0% of the children produced a target act before attempting to open the drawer or box. These data confirm what was already evident from Experiment 2: The target acts had a low spontaneous baseline rate, and when children performed them it was due to watching the adult's demonstration.

A one-way ANOVA showed a significant main effect for the number of target acts produced as a function of experimental group during the response period, $F(2, 33) = 18.14$, $p < .001$. Follow-up pairwise comparisons using the Newman–Keuls procedure ($p < .05$) showed that children in the model-successful group ($M = 83\%$, $SD = 33\%$) were significantly more likely to produce the target acts than children in the model-unsuccessful group ($M = 50\%$, $SD = 37\%$) and that they, in turn, were significantly more likely to do so than the controls in the no-demonstration group ($M = 8\%$, $SD = 19\%$; see Figure 3). A finer grained examination of the data showed that the same significant pattern of target act production was obtained even on the trials (88%) in which the children tried their own means first (i.e., their first act was to pull directly on the drawer or box lid) and thus had to switch from their own preferred means to the one they remembered the adult had demonstrated in the past.

Taken together with Experiments 1 and 2, these results support the hypothesis that children selectively imitate and do so depending on a combination of their own and others' experiences with the task. First, there is evidence that the children imitated the model's effective means even after having an initial, easy experience with the task. The significantly higher levels of target act production in the model-successful group versus the no-demonstration group show that the children did not just spontaneously produce the distinctive target acts in response to the difficulty of the task (e.g., when the third drawer or box did not open for them). Additionally, the difference in target act production between the model-unsuccessful and no-demonstration groups shows that the children learned from the acts demonstrated by the model, at least to some extent, even when those means appeared to be unsuccessful. However, the fact that children in the model-unsuccessful group did not imitate as often as those in the model-successful group shows that the children took the model's efficacy into account in guiding their imitation from memory. Finally, the children's switching to the distinctive target act as a function of experimental group suggests that children can imitate a model from memory after first trying an intervening motor act (their own means).

General Discussion

It is well documented that young children are prolific imitators. Researchers have now begun to examine the conditions that regulate imitation (e.g., Repacholi & Meltzoff, 2007) and have recently raised the possibility that children imitate "too much." Several recent articles have reported that preschool-age children imitate unusual and unnecessary actions, raising the notion that human children compulsively duplicate the way others act (e.g., Horner & Whiten, 2005; Lyons, Young, & Keil, 2006; Whiten et al., 1996). The current experiments show that although young children can and do imitate the exact actions and means used by others, they do so flexibly, selectively, and in a rule-governed manner that we can begin to describe in some detail.

In particular, these experiments have established several factors that regulate children's imitation. We found that children varied their imitative responses as a function of whether their own prior means, and those they observed performed by others, were causally efficacious in reaching the goal. Further, going beyond the previous studies that had reported flexibility in imitation (e.g., Bekkering et al., 2000; Carpenter et al., 1998, 2005; Gergely et al., 2002; Gleissner et al., 2000; Williamson & Markman, 2006), Experiment 1 was designed so that the children in both of our experimental groups saw *identical* demonstrations. Thus, the children's imitation of the same visual stimulus varied as a function on their own prior experiences with the task (which were under experimental control).

In Experiment 1, the crucial self-experience came before the children saw the adult's demonstration. Children used their prior experiences to guide when and what they imitated. When the task was difficult, the children were more likely to imitate versus when the task was easy. Monitoring one's own prior experiences provides important information about the probability that certain acts and behaviors do not lead to successful outcomes and increases the probability that children will incorporate alternative means through observation of the acts of others. This is compatible with a causal Bayes net framework (Jaynes, 1983; Pearl, 1988; Russell & Norvig, 2002; Tenenbaum, Griffiths, & Kemp, 2006), which provides a mathematical formalism for combining information from one's own interventions (the prior experience in the current experiments) with information from observation (the adult's demonstration in the current experiments). The findings reported here provide clear evidence that young children seamlessly integrate interventions they perform with interventions they see performed by others to infer the most causally efficacious solution to a novel task, thus contributing developmental findings to the causal Bayes net literature (Gopnik & Schulz, 2007; Shon, Storz, Meltzoff, & Rao, 2007).

The children also showed selective imitation when the task first became difficult after the model's demonstration (Experiment 3). After an initially easy experience, when children expected the problem to be easy to solve by their own means, they still encoded and stored the adult's distinctive acts and were able to use them after their own attempts failed. These results present an encouraging picture about learning: Young children learn from adults even when the children have reason to believe that they do not need to do so and already know how to do something. In Experiment 3, the majority of the children tried their own previously successful means, and when they encountered difficulties they switched their behavior using their memory of the adult's now-absent demonstration as a guide.

Preschoolers may often use imitation this way in everyday life. When children hit a snag in problem solving, they may seek out another person's means or think back to what their parents or other experts did. Just because the children do not immediately imitate an adult's means does not mean that they do not have a rich memory for the model's demonstration that they can access when needed (Meltzoff, 2007b; Meltzoff & Moore, 1994; Williamson & Markman, 2006). The current research goes beyond many previous demonstrations of deferred imitation by showing that children tried their own action first and then relied on their memory of the adult's acts to switch their behavior. Thus, the results of Experiment 3 do not merely bridge a temporal delay but establish that children can at first perform an intervening action that fails and, without any other input from the adult, then modify their initial, ineffective efforts on the basis of memory of the now-absent model.

The children in the current experiments profited from their own hands-on experiences with the tasks. This connects with work in education emphasizing the value of prior experience in structuring a student's understanding of a physical demonstration or verbal instruction from a teacher. Several lines of research have documented that prior experience confronting difficulties with a problem can help students be more ready to learn from an expert (e.g., Alexander & Winne, 2006; Chi, Siler, Jeong, Yamauchi, & Hausmann, 2001; Schwartz & Martin, 2004). Prior hands-on experiences may be particularly motivating or engaging for young children. For example, a difficult experience may provide a strong incentive for encoding and subsequently recalling another's novel way of doing things. One future direction is to investigate the delays that can be tolerated and still have the child's own prior experience influence his or her imitation of the model.

In addition to the influence of their own experiences, we found that the extent to which the children adopted the experimenter's means varied as a function of the adult's efficacy with the task. When the adult's means were not effective for completing the task, the children were less likely to imitate those acts. Children showed this selectivity in imitation both after they had a difficult prior experience with a task (Experiment 2) and when they had an easy prior experience and then ran into unexpected difficulties (Experiment 3). The results of Experiment 3 suggest that children can learn from a model's unsuccessful actions (the production of target acts in the model-unsuccessful group exceeded baseline rates) but that they preferentially imitate successful adults at higher rates than unsuccessful ones, with implications beyond the basic science for early education and learning from peers and siblings.

It is worth highlighting two cognitive-developmental underpinnings of imitation on the current tasks. First, memory and inhibition skills are necessary to override one's own practiced means in favor of another person's more effective means. Second, an understanding of causal reasoning (Gopnik & Shulz, 2007) and the plurality of means to a given end is implicated. Children need to understand that different means can be used to achieve the same goal, that some means are more causally efficacious than others, and that one's own preferred means in one context may not be effective in another. The current research establishes a stable pattern of results from which younger children (and even infants) can be compared. Such extensions, using procedures similar to those developed here, will help us identify the relevant developmental trajectory.

The current findings and hypotheses also may enrich our understanding of the imitation deficits in children with autism. Hobson and Lee (1999) reported that although children with autism could reproduce the overall goal or outcome of a demonstration, they were poor at reproducing the style (e.g., the harshness or gentleness of the action) that the model used. On the basis of the current work, it is possible that giving children a first-hand experience with a difficult task could make them more receptive to the style used by an adult model. Such a manipulation could be helpful for characterizing the scope, limitations, and similarities between imitation in children with autism and typically developing children.

Nonhuman primates are less likely to copy a model's precise means than are typically developing human children, and this has been used to support claims about constraints on imitative learning in nonhuman primates (e.g., Call, Carpenter, & Tomasello, 2005; Horner & Whiten, 2005; Nagell et al., 1993; Povinelli, 2000; Tomasello, 1999; Want & Harris, 2002; Whiten et al., 1996, 2004). Past research shows that nonhuman primates disregard another's precise means if they have a first-hand experience that those means are not necessary for completing a task (Whiten et al., 1996). It would be interesting to know whether a first-person, hands-on experience with a difficult task may have the opposite effect, as it did in the current studies. After having a difficult experience using their own means, nonhuman primates may show greater attention to or imitation of the precise means demonstrated by a successful model. Our current procedures and experimental manipulations may therefore be useful for uncovering conditions under which nonhuman species imitate the model's more precise actions or techniques versus simply emulating the end result of a demonstration (Call et al., 2005).

In addition to using imitation to learn about physical causality, human children also use imitation socially, to affiliate or communicate with others (Carpenter, 2006; Meltzoff, 2007a; Nielsen, 2006; Uzgiris, 1981). Behaviors used as means for accomplishing physical goals often involve causally plausible manipulations of objects (e.g., using a tool or pushing a button to open a drawer), but those used for social causality can be more distinctive, arbitrary, and idiosyncratic, especially when there is a shared history. The imitation of unusual social acts is often incorporated into identification routines (e.g., a private handshake or cultural practice) and used in social communication to establish and maintain common ground. Important cultural conventions often revolve around arbitrary acts; the in-group knows the routine, which fosters group membership and cohesion. Thus, the criteria used for choosing what to imitate may be very different in cases of physical causality versus social causality. The standard physical causality case may lead children to emphasize the goal (what has been called emulation), and the standard case of social causality and communication may lead children to emphasize the precise style and manner of the acts. It is important to note, however, that the current experiments show that even in cases of physical causality, prior experience with the task and evidence about the causal efficacy of the model can focus children on the precise means used.

In conclusion, preschoolers were able to acquire novel strategies and means for solving problems on the basis of the acts they observed others perform. These results suggest that imitation is an effective and adaptive learning mechanism for young children. The children in our experiments used their own prior experiences to guide whether they chose to imitate the precise means used by others. They selectively imitated the precise actions they observed in those cases in which another's means were likely to be important for completing the task at hand. The children were not confined to rote, fixed, and automatic imitation but flexibly and selectively varied what means they reproduced depending on specific factors in the situation. In choosing what to imitate and when to do so, children combined information from two sources: prior experience of the self, and the observed causal efficacy of the acts of others.

References

Alexander, P. A., & Winne, P. (Eds.). (2006). *Handbook of educational psychology* (2nd ed.). Mahwah, NJ: Erlbaum.

Bekkering, H., Wohlschläger, A., & Gattis, M. (2000). Imitation of gestures in children is goal-directed. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 53*A, 153–164.

Brand, R. J., Baldwin, D. A., & Ashburn, L. A. (2002). Evidence for "motionese": Modifications in mothers' infant-directed action. *Developmental Science, 5,* 72–83.

Brugger, A., Lariviere, L. A., Mumme, D. L., & Bushnell, E. W. (2007). Doing the right thing: Infants' selection of actions to imitate from observed event sequences. *Child Development, 78,* 806–824.

Call, J., Carpenter, M., & Tomasello, M. (2005). Copying results and copying actions in the process of social learning: Chimpanzees *(Pan troglodytes)* and human children *(Homo sapiens). Animal Cognition, 8,* 151–163.

Carpenter, M. (2006). Instrumental, social, and shared goals and intentions in imitation. In S. J. Rogers & J. Williams (Eds.), *Imitation and the social mind: Autism and typical development* (pp. 48–70) New York: Guilford Press.

Carpenter, M., Akhtar, N., & Tomasello, M. (1998). Fourteen- through 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behavior & Development, 21,* 315–330.

Carpenter, M., Call, J., & Tomasello, M. (2002). Understanding "prior intentions" enables two-year-olds to imitatively learn a complex task. *Child Development, 73,* 1431–1441.

Carpenter, M., Call, J., & Tomasello, M. (2005). Twelve- and 18-month-olds copy actions in terms of goals. *Developmental Science, 8,* F13–F20.

Chi, M. T. H., Siler, S. A., Jeong, H., Yamauchi, T., & Hausmann, R. G. (2001). Learning from human tutoring. *Cognitive Science, 25,* 471–533.

Csibra, G., & Gergely, G. (2006). Social learning and social cognition: The case for pedagogy. In Y. Munakata & M. H. Johnson (Eds.), *Processes of change in brain and cognitive development: Attention and performance XXI* (pp. 249–274). Oxford, England: Oxford University Press.

Fernald, A., & Simon, T. (1984). Expanded intonation contours in mothers' speech to newborns. *Developmental Psychology, 20,* 104–113.

Fernald, A., Taeschner, T., Dunn, J., Papousek, M., de Boysson-Bardies, B., & Fukui, I. (1989). A cross-language study of prosodic modifications in mothers' and fathers' speech to preverbal infants. *Journal of Child Language, 16,* 477–501.

Gattis, M., Bekkering, H., & Wohlschläger, A. (2002). Goal-directed imitation. In A. N. Meltzoff & W. Prinz (Eds.), *The imitative mind: Development, evolution, and brain bases* (pp. 183–205) Cambridge, England: Cambridge University Press.

Gergely, G., Bekkering, H., & Király, I. (2002, February 14). Rational imitation in preverbal infants. *Nature, 415,* 755.

Gleissner, B., Meltzoff, A. N., & Bekkering, H. (2000). Children's coding of human action: Cognitive factors influencing imitation in 3-year-olds. *Developmental Science, 3,* 405–414.

Gopnik, A., & Schulz, L. (Eds.). (2007). *Causal learning: Psychology, philosophy, and computation.* Oxford, England: Oxford University Press.

Harnick, F. S. (1978). The relationship between ability level and task difficulty in producing imitation in infants. *Child Development, 49,* 209–212.

Hobson, R. P., & Lee, A. (1999). Imitation and identification in autism. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 40,* 649–659.

Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees *(Pan troglodytes)* and children *(Homo sapiens). Animal Cognition, 8,* 164–181.

Jaynes, E. T. (1983). Prior probabilities, In R. D. Rosenkrantz (Ed.), *E. T. Jaynes: Papers on probability, statistics and statistical physics* (pp. 116–130). Dordrecht, the Netherlands: Reidel. (Reprinted from *IEEE Transactions on Systems Science and Cybernetics, SSC-4,* 227–241, 1968.)

Kuhl, P. K., Andruski, J. E., Chistovich, I. A., Chistovich, L. A., Kozhevnikova, E. V., Ryskina, V. L., et al. (1997, August 1). Cross-language analysis of phonetic units in language addressed to infants. *Science, 277,* 684–686.

Lyons, D. E., Young, A. G., & Keil, F. C. (2006, May). *Observing an adult model can disrupt children's detection of causally irrelevant actions.* Poster presented at the meeting of the Association for Psychological Science, New York.

Meltzoff, A. N. (1988). Infant imitation after a 1-week delay: Long-term memory for novel acts and multiple stimuli. *Developmental Psychology, 24,* 470–476.

Meltzoff, A. N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology, 31,* 838–850.

Meltzoff, A. N. (2007a). “Like me”: A foundation for social cognition. *Developmental Science, 10,* 126–134.

Meltzoff, A. N. (2007b). The “like me” framework for recognizing and becoming an intentional agent. *Acta Psychologica, 124,* 26–43.

Meltzoff, A. N., & Moore, M. K. (1994). Imitation, memory, and the representation of persons. *Infant Behavior and Development, 17,* 83–99.

Nagell, K., Olguin, R. S., & Tomasello, M. (1993). Processes of social learning in the tool use of chimpanzees *(Pan troglodytes)* and human children *(Homo sapiens). Journal of Comparative Psychology, 107,* 174–186.

Nielsen, M. (2006). Copying actions and copying outcomes: Social learning through the second year. *Developmental Psychology, 42,* 555–565.

Pearl, J. (1988). *Probabilistic reasoning in intelligent systems: Networks of plausible inference.* San Francisco: Morgan Kaufmann.

Povinelli, D. J. (2000). *Folk physics for apes: The chimpanzee's theory of how the world works.* New York: Oxford University Press.

Repacholi, B. M., & Meltzoff, A. N. (2007). Emotional eavesdropping: Infants selectively respond to indirect emotional signals. *Child Development, 78,* 503–521.

Russell, S., & Norvig, P. (2002). *Artificial intelligence: A modern approach* (2nd ed.). Englewood Cliffs, NJ: Prentice Hall.

Schulz, L. E., Hooppell, C., & Jenkins, A. C. (in press). Judicious imitation: Children differentially imitate deterministically and probabilistically effective actions. *Child Development.*

Schwartz, D. L., & Martin, T. (2004). Inventing to prepare for future learning: The hidden efficiency of encouraging original student production in statistics instruction. *Cognition and Instruction, 22,* 129–184.

Shon, A., Storz, J. J., Meltzoff, A. N., & Rao, R. P. N. (2007). A cognitive model of imitative development in humans and machines. *International Journal of Humanoid Robotics, 4,* 387–406.

Sibulkin, A. E., & Uzgiris, I. C. (1978). Imitation by preschoolers in a problem-solving situation. *Journal of Genetic Psychology, 132,* 267–275.

Tenenbaum, J. B., Griffiths, T. L., & Kemp, C. (2006). Theory-based Bayesian models of inductive learning and reasoning. *Trends in Cognitive Sciences, 10,* 309–318.

Tennie, C., Call, J., & Tomasello, M. (2006). Push or pull: Imitation vs. emulation in great apes and human children. *Ethology, 112,* 1159–1169.

Tomasello, M. (1999). *The cultural origins of human cognition.* Cambridge, MA: Harvard University Press.

Uzgiris, I. C. (1981). Two functions of imitation during infancy. *International Journal of Behavioral Development, 4,* 1–12.

Want, S. C., & Harris, P. L. (2001). Learning from other people's mistakes: Causal understanding in learning to use a tool. *Child Development, 72,* 431–443.

Want, S. C., & Harris, P. L. (2002). How do children ape? Applying concepts from the study of non-human primates to the developmental study of “imitation” in children. *Developmental Science, 5,* 1–13.

Whiten, A., Custance, D. M., Gomez, J., Teixidor, P., & Bard, K. A. (1996). Imitative learning of artificial fruit processing in children *(Homo sapiens)* and chimpanzees *(Pan troglodytes). Journal of Comparative Psychology, 110,* 3–14.

Whiten, A., Horner, V., Litchfield, C., & Marshall-Pescini, S. (2004). How do apes ape? *Learning and Behaviour, 32,* 36–52.

Williamson, R. A., & Markman, E. M. (2006). Precision of imitation as a function of preschoolers' understanding of the goal of a demonstration. *Developmental Psychology, 42,* 723–731.

Wohlschläger, A., Gattis, M., & Bekkering, H. (2003). Action generation and action perception in imitation: An instance of the ideomotor principle. *Philosophical Transactions of the Royal Society: Biological Sciences, 358,* 501–515.

Received October 26, 2006
Revision received June 8, 2007
Accepted July 16, 2007 ■