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Gradations of emulation learning in infants' imitation of actions on objects

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Abstract

This study explored different gradations of emulation in the imitation of actions on objects by 17-month-olds. Experiment 1 established levels of behavioral reproduction following prerecorded video demonstrations similar to those levels following live demonstrations. In Experiment 2, two digitally modified videos, where object movements or body movements critical to producing the target action were highlighted in isolation, were developed. Infants produced the target action equally frequently by observing the object movement video and observing the unmodified video. In contrast, their performance was much less successful based on the body movement video. In Experiment 3, the performance obtained following the object movement video was similar to that following a further video that emphasized the object movements produced in unsuccessful attempts to produce the target action. These findings suggest that emulation in the form of object movement reenactment or affordance learning plays a role in the social learning of actions on objects during infancy.

Keywords: Imitation; Emulation learning; Affordance learning; Object movement reenactment; Mimicry; Social learning

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Introduction

Imitation is a current focus of research in many disciplines (Dautenhahn & Nehaniv, 2002; Hurley & Chater, 2005; Meltzoff & Prinz, 2002). In contemporary comparative and developmental studies, many authors have argued for the phylogeny of imitation across human and nonhuman primates (Heyes, 1998; Tomasello, Kruger, & Ratner, 1993; Whiten, Horner, Litchfield, & Marshall-Pescini, 2004). Key questions include whether imitation in general guides the behavior of nonhuman species and whether imitation plays an essential role in human infants' acquisition of cultural skills. The strongest support for the latter claim comes from a growing consensus about the role of intention reading in imitative actions (Bekkering, Wohlschläger, & Gattis, 2000; Carpenter, Akhtar, & Tomasello, 1998; Carpenter, Call, & Tomasello, 2002, 2005; Meltzoff, 1995). These studies showed that various types of social cues provided children with the opportunity to learn about a demonstrator's goal or intention, leading them to respond by producing the same outcome as the demonstrator.

Meltzoff's (1995) study was the first to claim that infants could imitatively learn a person's intended actions using his or her unsuccessful actions. In that study, 18-month-olds saw an adult attempt but fail to achieve a target action on an object. The result was that the infants in the failed attempt condition completed the target action as often as those in the full demonstration condition and more frequently than the infants who had either observed the adult manipulate the relevant part of the object without an apparent goal or received no demonstration at all. This result has now been well replicated (Bellagamba & Tomasello, 1999; Huang, Heyes, & Charman, 2002; Johnson, Booth, & O'Hearn, 2001; Sanefuji, Hashiya, Itakura, & Ohgami, 2004).

Carpenter and colleagues (1998) showed that infants could use vocal cues to differentially copy the model's intentional actions. They presented 16-month-olds with an intentional action (marked by the model saying "There!") and an accidental action (marked by the model saying "Whoops!") in sequence. Both actions produced the same outcome, namely that infants subsequently tended to imitate the intentional action to reproduce the outcome. Carpenter and colleagues (2002) investigated the ability of 2-year-olds to use a variety of social cues in a sequential tool-use task (e.g., pulling out a pin and opening the door of a box). Before watching a correct demonstration, children were initially presented with the end state (the opened box), the intentional context (seeing the model open other boxes), or unsuccessful attempts. Infants from two additional control groups saw either the demonstration only or an irrelevant action before the correct demonstration. The researchers found that infants in each of the three prior intention conditions not only produced the target action but also copied the action style more often than did either control group.

Recent research, however, has begun to question whether what is typically called imitation in developmental research might actually represent an array of different social learning processes. Want and Harris (2002) listed three categories of action that have typically been modeled in the literature: (1) bodily movements, (2) simple actions on objects, and (3) complex actions on objects (including tool use). In looking for Categories 2 and 3, the presence of objects potentially evokes a number of mechanisms of social learning. In object contexts, nonintentional aspects of a demonstration may be as powerful as intention cues in guiding infants to coincidentally reproduce the model. The aim of the current work was to examine in detail the type of social learning that falls into Category 2 in Want and Harris's framework. Specifically, we wanted to compare the influences of the object motions and the model's bodily motions, both of which lead to the end state of a novel action.

This rationale is both theoretical and methodological. First, using the behavioral reenactment technique, it has been claimed that infants anticipate the intentions of others through the body movements of the model manipulating the objects. Observation of the body movements critical to manipulating a novel object may be sufficient for infants to infer the model's intentions directed to the object. Second, observation of object motion is likely to allow infants to access the stimulus consequences of observed behavior. Separating object motion from other aspects of the display is important to explore several emulation learning processes that involve learning about object properties. This type of study has long been of interest to comparative psychologists and is now being applied to the developmental approach (e.g., Huang et al., 2002; Thompson & Russell, 2004; Want & Harris, 2001).

The match between the actions of the demonstrator and those of the observer has been characterized in several ways within comparative psychology (Galef, 1988; Heyes, 1994; Spence, 1937; Thorpe, 1963; Whiten & Ham, 1992; Whiten et al., 2004). Some explanations of nonimitative social learning include local enhancement, stimulus enhancement, mimicry, and emulation. Depending on how it is characterized, many of these distinctions have yet to filter through to the developmental study of imitation. In the current work, we were particularly interested in different emulation learning possibilities.

Since Wood (1989) first described this term, different researchers have taken "emulation" to mean slightly different things. According to Tomasello (1990, 1996), emulation refers to the tendency of an observer to skip the model's strategy and leap to the effects of the model's behavior on the environment (e.g., affordances). Whiten and colleagues suggested that emulation is an intelligent process in which an observer actively selects and extracts information about the outcome of the demonstration (Whiten & Custance, 1996). They distinguished four subtypes of emulation—end state emulation, goal emulation, object movement reenactment, and affordance learning—with the first two subtypes involving sensitivity to observed outcomes and the latter two subtypes involving sensitivity to observed object movements (Custance, Whiten, & Fredman, 1999; Whiten & Ham, 1992; Whiten et al., 2004). In *end state emulation*, the presence of an end result motivates an observer to replicate the result without explicitly encoding it in relation to the model's goal. In *goal emulation*, an observer attributes a goal to the model while attempting to devise his or her own strategy to reproduce the end result. When an observer sees an object or its parts move, and that movement leads to a salient outcome, seeing the object movement might motivate the observer to reproduce the outcome via *object movement reenactment*. *Affordance learning* refers to a process whereby an observer detects stimulus consequences, such as dynamic properties and temporal–spatial causal relations of objects, through watching the object movements. Whiten and colleagues (2004) recently redefined object movement reenactment, goal emulation, and end state emulation as subtypes of a "copying" category, arguing that these processes involve copying something from the model. However, in the current study, we prefer to take object movement reenactment as a subtype of emulation, emphasizing the role of object movement in enhancing the tendency to replicate an observed outcome.

The definition of "imitation" in the literature remains as controversial as that of emulation. There are two main claims in contemporary research. The intentionality-based claim defines imitation in terms of behavioral reproduction that implicates an understanding of the intentional state underlying the model's behavior (e.g., Tomasello et al., 1993). Under this view, behavioral reproduction without attribution of goals or intentions to the model is not "true" imitation and would be what Tomasello (1996) called "mimicry." An alternative claim defines imitation as "copying by an observer a novel feature of the body movement of a demonstrator" (Heyes, 2001, p. 254). Heyes and Ray (2002) argued that a dichotomy between imitation and mimicry not only conflates matching behavior guided by intention reading with that based on the observable outcome of the model's actions but also conceals possible adaptive significance of mimicry. Heyes (2001) ascribed a crucial role of copying body movements to imitation and distinguished it from emulation in which behavioral reproduction is due to observed object movements. Whiten and colleagues (2004), however, suggested that emulation and imitation vary with respect to the degree of match between the behaviors of the model and the observer. In the current study, we took Heyes's definition to draw a broad distinction between imitation and emulation, recognizing the inherent possibility that the presence of objects recruits learning by emulation.

Indeed, emulation has not been routinely ruled out as an alternative to imitation within developmental psychology. Procedures that discriminate between imitation and emulation are rare. In the current study, we placed different emulation learning possibilities under the microscope, capitalizing on a recent study by Huang and colleagues (2002) that examined whether affordance detection could provide an alternative explanation for the behavioral reenactment data reported by Meltzoff (1995).

In the emulation learning condition (Huang et al., 2002, Experiment 1), 19-month-olds were exposed to the initial state and end state of the target action without seeing the adult transform the object (by using a screen). In the spatial contiguity condition (Huang et al., 2002, Experiment 2), 17-month-olds saw the adult move the target-relevant parts of the object set close to one another but make no attempt to bring about the target action. Counting infants' first acts only, performance was most efficient following the full demonstration model. However, when scoring infants' responses within the 20-s response period as the criterion used by Meltzoff, the emulation learning and spatial contiguity models elicited as many target actions as did the failed attempt or full demonstration model. The pattern of findings implies that intention attribution is not necessary, and that emulation is potentially sufficient, to induce production of the target action in the behavioral reenactment procedure.

In the current work, we explored further whether the object movement that leads to the end state transformation of a novel object motivates infants to replicate that end state (object movement reenactment). Alternatively, the replication might be induced by the model's body movement per se (mimicry). To evaluate the relative contributions of object movement and body movement normally observable in a model's performance, however, one will need a different type of stimulus display in which only information about body or object movement is made available. To this end, we exploited digitally modified videos. After confirming that infants produced the target action as often from a videotaped demonstration as from a live demonstration, the body or object movement originally recorded on videotape was digitally removed (by blocking out the movable part of the object set or the model's torso and hands). Therefore, with the initial and end states held constant, only object movement information was presented in one condition and body-based information was presented in a second condition.

If object movement is a necessary component of the observed action, performance should be much less successful when it is removed. If, however, both object movement information and body movement information are necessary components, performance based on the unmodified video model should be more efficient than performance based on either of the simplified video models.

Experiment 1

The aim of Experiment 1 was to establish that infants could replicate actions with objects they have seen modeled on the computer monitor. Some infants watched the demonstrator produce the target action live, some watched the demonstrator produce the target action on prerecorded videotape, and some were exposed to the object and the demonstrator not acting on the object at all. This study was designed with the purpose of laying the foundation for making modified versions of the video in Experiment 2. If target reproduction following the video demonstration were similar to that following the live model, this videotape would be further simplified to isolate distinct aspects of the demonstration (i.e., body movement vs. object movement).

Method

Participants

In all of the current experiments, participants were recruited from a number of health centers and hospitals in Hualien City, Taiwan. All were ethnic Chinese. A total of 30 infants (17 boys and 13 girls, mean age = 17.1 months, $SD = 0.8$) participated in Experiment 1. An additional 4 infants were excluded from the final sample due to failure to attend to the monitor (1), mother's prompts (1), fussiness (1), or a videotaping fault (1).

Apparatus

The test stimuli consisted of replications of the five objects used in Meltzoff's (1995) study, but minor alterations were made to the square and dowel.[1] The five objects were a dumbbell-shaped toy that could be pulled apart and put together again ("dumbbell"), a box with an underlying buzzer that could be activated with a wooden stick going into a recessed button on the top of the box ("box/stick"), a loop that could be draped over a prong that protruded horizontally from a vertical rectangular board ("prong/loop"), a chain of beads that could be placed into a cup-like cylinder ("cylinder/beads"), and a plastic square with a round hole in the center that could be put over a vertical dowel set in a wooden base plate ("dowel/square").

Procedure

All participants were tested individually at a laboratory in the department. On arrival at the department, the parent and child were led to a play area adjacent to the test room. While the experimenter explained the procedure to the parent, an assistant used stuffed puppets and plastic toys to engage the child in joint play. This warm-up was used to familiarize the child with the laboratory and workers. When the child seemed comfortable and was willing to handle the toy that the experimenter handed to him or her, the child and parent were led to the test room.

The child was seated in a high chair in front of a table (90 × 160 cm) opposite the experimenter. The parent sat next to the child. A computer monitor (17-in. LCD) was situated to the right of the experimenter at a distance of 80 cm from the child and at a 60° angle to the left of the child. The monitor was always on the table during testing, but only the video group saw prerecorded demonstrations on the screen. Two digital camcorders, focusing on the head, hands, and torso of the child and the surface of the table, were fixed on a tripod and stood behind and to the left and right of the experimenter, respectively. After the child was settled, the experimenter reminded the parent not to speak or act in any way that might influence the child's response and then started the first demonstration. Participants were randomly assigned to one of the three conditions (live, video, or baseline), resulting in 10 children per condition. Sequences for the test items were counterbalanced within each condition.

The live condition followed the procedure used by Meltzoff (1995) and Huang and colleagues (2002). The pilot study showed that infants in the video condition were impatient to start when they had watched the demonstration on the computer monitor for the second time. The action was repeated twice in the current study rather than three times as in previous research. The demonstration consisted of an initial state, a transformation phase, and an end state, each lasting for approximately 3 s.

[1] To reduce manipulatory requirements for fitting the hole over the dowel, a 4-cm diameter hole replaced the 2.5-cm diameter hole in the original design. The two edges of the square were elevated so that infants could raise the square from the table easily. In addition, the plastic square that was transparent in the original design was painted red to make it perceptually salient when observed on the computer monitor.

Thus, the experimenter produced the action twice in approximately 20 s. As in previous studies, the experimenter used the vocal words "look over here" to attract the child's attention each time he started. After the demonstration, the experimenter restored the object to its initial state and presented it on the table directly in front of the child.

For the dumbbell, the action demonstrated was to pick up the dumbbell by the cubes and pull outward so that it came apart into two halves. For the box/stick, the action demonstrated was to pick up the stick and use it to push in the recessed button, which then activated the buzzer inside the box. For the prong/loop, the action demonstrated was to raise the loop up to the prong and drape it over so that the loop rested on the prong. For the cylinder/beads, the action demonstrated was to raise the chain of beads up over the opening of the cylinder and then to lower them down into the opening so that the chain was deposited on the bottom of the cylinder. For the dowel/square, the action demonstrated was to pick up the square and put the hole in the center over the dowel in the wooden base plate.

In the video condition, the experimenter showed the infant prerecorded demonstrations on a computer monitor. Similar to the live demonstration, the videotaped demonstration consisted of an initial state, a transformation phase, and an end state. The action was repeated twice and lasted approximately 20 s. As in the live condition, the demonstrator on the monitor used the words "look over here" to attract the child's attention each time he or she was about to pick up the object. There were five prerecorded clips. The beginning of each clip was made up of a cartoon still (e.g., Pooh, Snoopy) that appeared prior to the initial state and was accompanied by a snatch of a children's song for 10 s. This helped to alert the child to the monitor. If the child did not look at the image, the experimenter would point to the screen or call the child's name. The parent was also allowed to do this but was asked not to label the action or object. During presentation of the video, the experimenter leaned forward and tilted his head to look at the screen. To avoid distracting the child from watching the video, the experimenter refrained from looking at the child. Furthermore, to motivate the child to pay attention to the object movements and the model's body movements, only the torso and hands of the model (and not the model's face), the object, and the surface of the table were recorded on video. At the end of each clip, the monitor turned to a blank screen. Then the experimenter retrieved the object that the child had already seen on the monitor from under the table, placed it in the initial state in front of the child, and said "your turn."

In the baseline condition, the child was exposed to the initial state of the object for 20 s. First, the experimenter picked up the object, set it in the initial state out of the child's reach, and laid both hands on the table beside the object. As in the live and video conditions, the experimenter used the words "look over here" to engage the child to look at the object. However, the object was never manipulated. After this presentation, the experimenter then placed the object in front of the child and said "your turn." This condition was included to assess the spontaneous rate of production of the target action in the absence of a model.

Scoring

Infants' responses to each of the five objects were coded from the videotapes. For each child, the video record included a series of five 20-s response periods. Studies from both developmental and comparative domains have shown that an observer's initial response following a demonstration is maximally informative about the imitation effect (e.g., Heyes & Saggerson, 2002; Huang et al., 2002; Whiten, Custance, Gomez, Teixidor, & Bard, 1996). We primarily scored whether the target action was produced as the child's first act. The rationale was that if infants learn about a modeled action through imitation, they should execute it efficiently without trial and error. In addition, we scored whether infants produced the target action based on their overall performance in the 20-s response period. Developmentalists have commonly adopted this scoring strategy (e.g., Devouche, 1998; Meltzoff, 1988b, 1988c, 1995). A comparison of performance at the first act and in the 20-s response period may provide some insight into alternative social learning processes implicated in the imitative ability of infants.

The operational definitions of the target act for each of the five objects were as follows (see also Huang et al., 2002, Appendix A). For the dumbbell, the child held the dumbbell by the two cubes and then pulled them outward so that the dumbbell split into two halves. For the box/stick, the child held the stick upright and used it to push the recessed button on the top of the box so that the buzzer inside the box was activated. For the prong/loop, the child raised the loop up to the prong and then put it over the ballpoint end so that the prong protruded through it; if the loop did not rest on the prong, it had to pass through the prong and go beyond its halfway point. For the cylinder/beads, the child raised the chain of beads up over the opening of the cylinder and then put the beads into the cylinder so that the beads were deposited on its base; the child could continue to hold the beads, but the beads had to be underneath the opening of the cylinder. For the dowel/square, the child picked up the square and then put the round hole in the center of the square over the dowel so that the dowel protruded through the round hole; the elevated edges of the square should stay in an upward position.

In addition, we scored the part of the object set that infants touched as their first act in terms of whether the first-touched part was consistent with or different from the part that the demonstrator had initially handled and whether they started by touching more than one part of the object set or did not respond at all. This measure has been used to explore children's behavioral reproduction strategies (Carpenter et al., 2002; Huang et al., 2002). Demonstrator-consistent parts were coded when infants touched the two cubes of the dumbbell, stick of the box/stick, loop of the prong/loop, beads of the cylinder/beads, and square of the dowel/square. Demonstrator-inconsistent parts were coded when infants touched the middle tube of the dumbbell, box of the box/stick, prong of the prong/loop, cylinder of the cylinder/beads, and dowel of the dowel/square. Touching more than one part was coded when infants touched both a demonstrator-consistent part and a demonstrator-inconsistent part.

The first author and a trained rater who was blind to the hypotheses of the study and the infants' condition assignments scored all test sessions independently.

Interrater agreement was 99% ($k = .97$) for target actions at the first act, 98% ($k = .96$) for target actions in the 20-s response period, and 93% ($k = .88$) for first-touched object parts.

Results

Table 1 gives mean target actions produced at the first act for each condition and item. The data were subject to a mixed-model analysis of variance (ANOVA) in which condition was the between-subjects factor and item was the within-subjects factor. There was a main effect of item, $F(4, 108) = 4.65$, $p = .002$, but this effect did not interact with condition, $F(8, 108) < 1$. The item effect was likely due to different levels of manual dexterity for handling the items. As shown in Table 1, the overall rate of reproductions with the cylinder/beads was high relative to the overall rates of reproductions with the other items. More important, the condition factor produced a main effect, $F(2, 27) = 18.5$, $p < .001$. Follow-up Bonferroni tests revealed that the rate of target production in the video condition was similar to that in the live condition and that each rate was higher than that in the baseline condition ($p = .002$ and $p < .001$, respectively).

Table 2 shows mean numbers of object parts that infants touched first. All infants readily picked up each object set as their first act. A one-way ANOVA indicated that there was no reliable difference in the mean number of first-touched object parts that were demonstrator consistent, $F(2, 27) = 1.07$, $p = .36$. In contrast, there was a significant difference in the mean number of first-touched object parts that were demonstrator inconsistent, $F(2, 27) = 10.03$, $p = .001$. Follow-up Bonferroni tests revealed that infants in the baseline condition initially touched the demonstrator-inconsistent parts of the objects more frequently than did infants in the live ($p = .001$) and video ($p = .01$) conditions who did not differ from each other.

Table 1
Experiments 1 to 3: Mean target actions produced at the first act across items and conditions

Condition	Individual items					Overall
	Dumbbell	Box/Stick	Prong/Loop	Cylinder/Beads	Dowel/Square	
Experiment 1						
Live	.80 (.42)	.50 (.53)	.50 (.53)	.90 (.32)	.30 (.48)	.60 (.23)
Video	.40 (.52)	.50 (.53)	.20 (.42)	.70 (.48)	.30 (.48)	.42 (.18)
Baseline	.10 (.32)	.00 (.00)	.00 (.00)	.30 (.48)	.10 (.32)	.10 (.14)
Experiment 2						
FD	.20 (.42)	.40 (.52)	.60 (.52)	.90 (.32)	.40 (.52)	.50 (.19)
BM	.20 (.42)	.20 (.42)	.20 (.42)	.10 (.32)	.00 (.00)	.14 (.14)
OM	.30 (.48)	.60 (.52)	.30 (.48)	.60 (.52)	.30 (.48)	.42 (.32)
Baseline	.00 (.00)	.10 (.32)	.10 (.32)	.10 (.32)	.00 (.00)	.06 (.14)
Experiment 3						
OM	.50 (.53)	.40 (.52)	.30 (.48)	.50 (.53)	.10 (.32)	.36 (.21)
OM (FA)	.00 (.00)	.50 (.53)	.40 (.52)	.30 (.48)	.40 (.52)	.32 (.19)

Note. Standard deviations are in parentheses. FD, full demonstration; BM, body movement; OM, object movement; OM (FA), object movement (failed attempt).

Table 2
Experiments 1 to 3: Mean numbers of object parts that infants first touched

Condition	Part touched consistent with the demonstration	Part touched different from the demonstration	Touched more than one part	No response
Experiment 1				
Live	.68 (.23)	.04 (.08)	.28 (.23)	.00 (.00)
Video	.66 (.16)	.10 (.11)	.24 (.16)	.00 (.00)
Baseline	.56 (.18)	.28 (.17)	.16 (.16)	.00 (.00)
Experiment 2				
FD	.78 (.20)	.10 (.11)	.12 (.14)	.00 (.00)
BM	.54 (.23)	.24 (.16)	.22 (.18)	.00 (.00)
OM	.74 (.16)	.14 (.16)	.10 (.11)	.02 (.06)
Baseline	.48 (.19)	.32 (.19)	.18 (.22)	.02 (.06)
Experiment 3				
OM	.80 (.21)	.10 (.17)	.10 (.14)	.00 (.00)
OM (FA)	.72 (.22)	.04 (.08)	.24 (.18)	.00 (.00)

Note. Standard deviations are in parentheses. FD, full demonstration; BM, body movement; OM, object movement; OM (FA), object movement (failed attempt).

A main effect of item was also found in the rate of target production in the 20-s response period (Table 3), $F(4,108)=3.52$, $p=.01$. As in the first act analysis, this effect did not interact with condition, $F(8,108)<1$. The rates of reproductions with the cylinder/beads and dumbbell were relatively high compared with those with the other items (particularly the prong/loop and dowel/square). There again was a main effect of condition, $F(2,27)=27.33$, $p<.001$. Bonferroni post hoc comparisons revealed that the rate of target production was as frequent in the video condition as in the live condition and that each rate was greater than that in the baseline condition

Table 3
Experiments 1 to 3: Mean target actions produced in the 20-s response period across items and conditions

Condition	Individual items					Overall
	Dumbbell	Box/Stick	Prong/Loop	Cylinder/Beads	Dowel/Square	
Experiment 1						
Live	.90 (.32)	.70 (.48)	.70 (.48)	.90 (.32)	.50 (.53)	.74 (.14)
Video	.70 (.48)	.80 (.42)	.40 (.52)	.70 (.48)	.30 (.48)	.58 (.20)
Baseline	.30 (.48)	.10 (.32)	.10 (.32)	.40 (.52)	.10 (.32)	.20 (.16)
Experiment 2						
FD	.30 (.48)	.80 (.42)	.60 (.52)	.90 (.32)	.40 (.52)	.60 (.19)
BM	.50 (.53)	.30 (.48)	.20 (.42)	.50 (.53)	.00 (.00)	.30 (.25)
OM	.70 (.48)	.90 (.32)	.60 (.52)	.70 (.48)	.30 (.48)	.64 (.25)
Baseline	.20 (.42)	.30 (.48)	.10 (.32)	.20 (.42)	.00 (.00)	.16 (.21)
Experiment 3						
OM	.70 (.48)	.60 (.52)	.60 (.52)	.80 (.42)	.30 (.48)	.60 (.16)
OM (FA)	.40 (.52)	.70 (.48)	.60 (.52)	.70 (.48)	.40 (.52)	.56 (.25)

Note. Standard deviations are in parentheses. FD, full demonstration; BM, body movement; OM, object movement; OM (FA), object movement (failed attempt).

(both *p*s < .001). Mean numbers of nontarget actions (and standard deviations) before succeeding were as follows: live, .38 (.45); video, .42 (.37); and baseline, .92 (.85). No significant difference was revealed as a function of condition, $F(3, 27) = 2.41$, $p = .111$.

Discussion

The principal purpose of Experiment 1 was to establish the rate of imitation from videotaped demonstrations as similar to that from live demonstrations. Performance following the video model was similar to that following the live model not only in the rate of target production but also in terms of behavioral strategy. Infants seeing either model outperformed infants in the baseline condition. Although the demonstrator's face was not observable in the clips, this did not appear to prevent infants from learning about the videotaped actions. The results of Experiment 1 are consistent with previous findings showing that infants can replicate single-step actions with objects they have seen modeled on television (e.g., Barr & Hayne, 1999; Meltzoff, 1988a). In the next experiment, the Experiment 1 videotape was further modified to explore the roles of object movement reenactment and mimicry in infants' imitation of actions on objects.

Experiment 2

Experiment 2 used three digitally modified versions of the Experiment 1 video. These versions specifically differed as to what aspect of the transformation was recorded on videotape. In the full demonstration condition, infants received both the body and object movement components of the target action. In the body movement condition, the movable part of the object set was digitally removed and only the body movement component was presented. In the object movement condition, the demonstrator was digitally removed and only the object movement component was presented. As before, the recorded actions included a sequence of an initial state, a transformation phase, and an end state. A critical difference among the three conditions was the type of source information recorded during the transformation.

The novel condition of object movement was designed to address one emulation learning hypothesis that infants base their replication of actions involving objects on observed object movements. The object movement reenactment tendency is assumed to work when object movement information is associated with a rewarding outcome (Custance et al., 1999). Although it is not clear to what extent the outcome would be particularly reinforcing, we assume that the object's end state provided information about affordances and that exposure to object movement might motivate a tendency toward reproducing the end state. The novel condition of body movement was designed to examine whether exposure to the central strategy and end state would be sufficient to induce replication of the target action. To keep potential sources of affordance information similar across conditions, the initial and end states were presented in each of the full demonstration, object movement, and body movement conditions. An additional baseline control, in which the video recorded only the initial state, was included to assess spontaneous performance. Experiment 2 aimed to test whether the effects of observing the full demonstration model could be interpreted differently in terms of the object movement or body movement component critical to producing the target action. So far as we are aware, the relative influences of object movement and body movement have not been clarified previously in the developmental study of imitation during infancy.

Method

Participants

A total of 40 infants (20 boys and 20 girls, mean age = 17.7 months, $SD = 0.8$) participated in Experiment 2. All were ethnic Chinese in Taiwan. An additional 6 infants were excluded from the final sample due to failure to attend to the computer monitor (3), mother's prompts (2), or fussiness (1).

Apparatus and test situation

The test materials were identical to those used in Experiment 1. All participants were tested individually at a laboratory in the department. The test setting and warm-up procedures followed those used in Experiment 1.

Procedure

Infants were randomly assigned to one of four conditions: full demonstration, body movement, object movement, or baseline. All infants received a specifically made video according to condition assignment. Each video consisted of five clips across five object sets. Sequences of clips were counterbalanced within each condition. As in Experiment 1, a cartoon shot accompanied by a children's song was recorded for 10 s at the beginning of each clip. Following this shot, the modified action was repeated twice within approximately 20 s. Table 4 compares aspects of information forming the four videos. The initial state and the end state included in these conditions were

Table 4
Experiment 2: Comparisons of source information comprising videos

Component	FD	BM	OM	Baseline
Initial state	Yes	Yes	Yes	Yes
Transformation phase				
Body movement	Yes	Yes	No	No
Object movement	Yes	No	Yes	No
End state	Yes	Yes	Yes	No
Alerting words	Yes	Yes	Yes	Yes
Demonstrator's face	No	No	No	No

Note. FD, full demonstration; BM, body movement; OM, object movement.

identical. The conditions differed specifically as to whether object movement or body movement information was removed from the transformation.

The initial state was actually a video frame displaying the initial state of the object set and the beginning position of the demonstrator's hands. The object set lay on the table between two hands that never contacted the objects. Note that the movable part (e.g., the stick of the box/stick) was always placed beside the right hand. The end state was a video frame displaying the end state of the object set and the terminal position of the demonstrator's hands (e.g., for the box/stick, a recorded beep was heard while the end state showed the demonstrator's right hand holding the stick that stood upright on the recessed button of the box). As before, the demonstrator's face was not recorded on the initial state or the end state; only the torso and hands were observable. Each state was displayed for a 3-s period (for frame samples, see Fig. 1).

Following the initial state, a transformation phase was recorded for approximately 4 s. The transformation began from the point where the demonstrator started to move his hands and ended at the point where the object set's configuration was completed. Specifically, the transformation provided information about the object movement or body movement causally related to the end state transformation. Recall that in Experiment 1 the demonstrator had to restore the end state to the initial state (e.g., remove the loop from the prong to the table) so as to perform the target action for a second time. It should be noted that the demonstration actually included the target action and its reversal. In Experiment 2, we wanted to emphasize the object and hand movement paths critical to achieving the target action. Thus, an important difference between Experiments 1 and 2 is that Experiment 2 did not include the reversal of the target action. Following the end state, infants were directly exposed to the initial state without witnessing the restoration process, and then the demonstration was repeated. Another purpose of cutting off the reversal was that we wanted to contrast key aspects of these videos inasmuch as infants in the full demonstration, body movement, and object movement conditions were equally exposed to the same initial and end states.

In the full demonstration condition, the transformation phase recorded both the object movement and body movement components of the target action. The clips were mainly a replication of the Experiment 1 video except for information about reversibility. In the body movement condition, the transformation phase recorded only the body movement component. This was attained by blocking out the movable part of the object set (e.g., stick of the box/stick) using the Chroma key of Adobe Premiere 6.5. Then the modified clip (30 frames/s) was superimposed on a prerecorded clip that recorded the wall, table, and static part of the object set (e.g., box of the box/stick) with the same filming conditions as the original version but without the demonstrator and movable part of the object set. Thus, the transformation phase included the static part of the object set and body movements generated in manipulation of the movable part. For example, the demonstrator raised his right hand that moved toward the box and stayed at a distance from the button in a stick-holding gesture (for a frame sample, see Fig. 1). In the object movement condition, in contrast, the transformation phase recorded only the object movement component. This was attained by blocking out the demonstrator digitally. Then the modified clip was

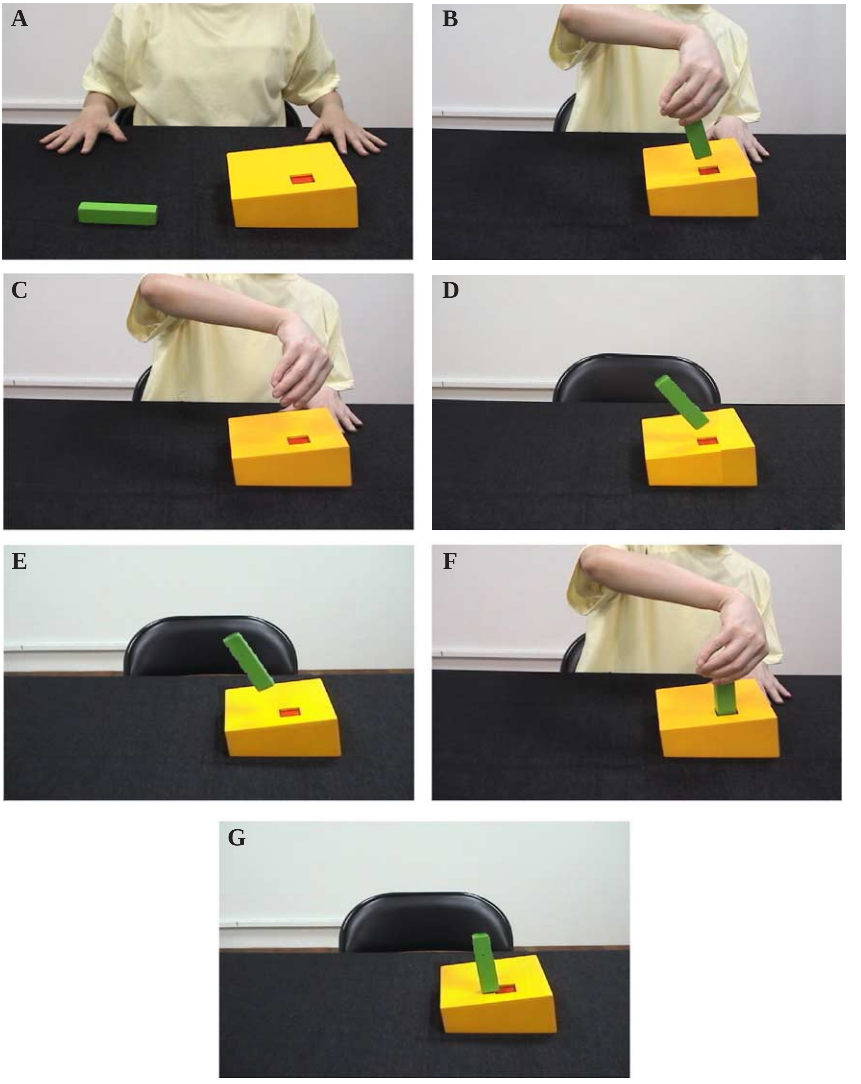

Fig. 1. Frame samples from Experiments 2 and 3. (A) Initial state. (B) Transformation phase, full demonstration. (C) Transformation phase, body movement. (D) Transformation phase, object movement. (E) Transformation phase, object movement (failed attempt). (F) End state (the beeper was activated). (G) Unconsummated result, object movement (failed attempt).

superimposed onto the prerecorded clip described previously. Thus, the transformation phase included the static part of the object set and object movements produced by the movable part in the absence of an agent. For example, the stick rose up, moved toward the box, and then touched the recessed button (for a frame sample, see Fig. 1). The vocal words "look over here" were also recorded on the transformation phase in each condition to alert the infants to the screen. In the baseline condition, only the initial state was presented on the computer monitor. The initial state from each clip was recorded for 20 s. The vocal words "look over here" were also recorded twice during this period to alert the infants to the video image.

Scoring

Infants were allowed 20 s to manipulate the objects immediately after watching one test clip. Infants' responses in each condition were coded from the videotapes. The scoring procedure and behavioral definitions of coding the target actions and first-touched object parts were identical to those described in Experiment 1. In addition, we scored the length of time each infant spent looking at each clip. The time was measured by reference to the character generator on the video record that displayed time in seconds and frames.

The first author and a trained rater scored all test sessions from the videotapes independently. The second rater was blind to the hypotheses of the experiment and the infants' condition assignments. Interrater agreement was 99% ($k = .98$) for target actions produced at the first act, 99% ($k = .98$) for target actions produced in the 20-s response period, and 96% ($k = .93$) for first-touched object parts.

Results

Tables 1 and 3 give mean target actions produced at the first act and in the 20-s response period for each condition and item. The data were subject to separate mixed-model ANOVAs. The first act analysis yielded a main effect of item, $F(4,144) = 3.08$, $p = .018$. This effect was likely to reflect the overall high rate of reproductions with the cylinder/beads relative to the overall rates of reproductions with the dumbbell and dowel/square. Importantly, the analysis that was the central interest of the current experiment indicated a main effect of condition, $F(3,36) = 10.30$, $p < .001$, with no reliable Item × Condition interactions, $F(12,144) = 1.41$, $p = .17$. Follow-up Bonferroni tests revealed that the rate in the object movement condition was as frequent as that in the full demonstration condition and that each rate was higher than that in the body movement ($p = .03$ and $p = .003$, respectively) or baseline ($p = .003$ and $p < .001$, respectively) condition. No difference was found between the latter two conditions.

Mean numbers of object parts that infants first touched can be seen in Table 2. Nearly all infants picked up each object set as their first act. A one-way ANOVA showed that there was a significant difference in the mean number of demonstrator-consistent parts of the objects, $F(3,36) = 5.50$, $p = .003$. Follow-up Bonferroni tests revealed that infants in the full demonstration and object movement conditions initially touched more demonstrator-consistent parts than did infants in the baseline condition ($p = .011$ and $p = .035$, respectively). A marginally significant difference was revealed between infants in the full demonstration condition and those in the body movement condition ($p = .063$). Similarly, a one-way ANOVA on the mean number of demonstrator-inconsistent parts of the objects indicated a significant difference, $F(3,36) = 3.93$, $p = .016$. Follow-up Bonferroni tests revealed only one reliable difference, namely that between the full demonstration and baseline conditions ($p = .022$).

There also was a main effect of item in the rate of target production in the 20-s response period, $F(4, 144) = 6.40$, $p < .001$, possibly due to the overall low rate of reproductions with the dowel/square relative to the overall rates of reproductions with the box/stick and cylinder/beads. This effect again did not interact with condition, $F(12, 144) = 1.18$, $p = .301$. As in the first act analysis, there was a main effect of condition, $F(3, 36) = 10.68$, $p < .001$. Follow-up Bonferroni tests revealed that the rate in the object movement condition did not differ from that in the full demonstration condition and that each rate was higher than that in the body movement ($p = .011$ and $p = .031$, respectively) or baseline ($p < .001$ and $p = .001$, respectively) condition. No difference was found between the latter two conditions. Mean numbers of nontarget actions (and standard deviations) before succeeding were as follows: full demonstration, .30 (.51); body movement, 1.05 (.99); object movement, .61 (.58); and baseline, 1.73 (1.69). A one-way ANOVA indicated a significant effect of condition, $F(3, 28) = 3.14$, $p = .041$. Follow-up Bonferroni tests revealed that infants in the full demonstration condition produced fewer nontarget actions than did infants in the baseline condition ($p = .043$).

Because the lengths of the video clips varied somewhat, percentages rather than durations were used in the looking time analysis. Mean percentages of time spent looking at the screen (and standard deviations) across the five video presentations were as follows: full demonstration, .78 (.12); body movement, .87 (.06); object movement, .82 (.10); and baseline, .60 (.14). A one-way ANOVA indicated a significant effect of condition, $F(3, 36) = 11.63$, $p < .001$. Follow-up Bonferroni tests showed that the mean percentage of total looking time in the baseline condition was lower than that in the full demonstration ($p = .005$), body movement ($p < .001$), or object movement ($p = .001$) condition. The latter three conditions did not differ from each other.

Discussion

The current results showed that seeing the demonstrator's body movements was not necessary to induce imitation of simple action on objects given that infants in the object movement condition, where body-based information was artificially removed, were as likely to produce the target action as were infants in the full demonstration condition. Furthermore, infants in both of these conditions produced the target action more often than did infants in the body movement and baseline conditions.

However, there was a different pattern with respect to the strategies used to produce the target action. In comparison with the baseline condition, the full demonstration model encouraged infants not only to initially contact a demonstrator-inconsistent part of the object set less often but also to generate fewer nontarget actions before succeeding in the 20-s response period. It is plausible that infants in the full demonstration condition adopted a more efficient strategy given that they could access actions, goals, and results directly from the demonstrator (Call & Carpenter, 2002) without needing to infer them. The full demonstration condition also provided infants with more retrieval cues at both the time of encoding and the time of responding. In contrast, the baseline condition exposed infants to the initial state only, and the static display should have required them to conduct more orientation and exploration of the real object. Despite the fact that infants in the object movement condition produced the target action more often than did infants in the baseline condition, the two groups did not appear to differ substantially in terms of behavioral strategies.

The effects of seeing the object movements are striking nonetheless given that the three conditions of full demonstration, body movement, and object movement permitted equal access to the initial state and the end state and that the vocalizations prerecorded to alert the infants to the computer monitor were identical. Importantly, the demonstrator's face was always not observable on the monitor screen. These methodological considerations ruled out potential sources of information about the agent's intentional state. However, infants in each condition received verbal and behavioral support from the experimenter. The observational situation was actually a joint activity between the infants and the experimenter. When the infants looked away, the experimenter drew their attention to the presentation by calling their names or pointing at the screen, and the experimenter handed the object to the infants and requested it back at the end of the response period. Given infants' propensity for joint attention behaviors, could interactions over the course of the procedure have served as a prior intention (cf. Carpenter et al., 2002), facilitating their understanding of the demonstrator's goal? We deem this explanation unlikely because the experimenter's behavior toward the monitor and the infants was similar across conditions.

A more likely explanation is that object movement is easily understandable (and perhaps more interesting) compared with (apparently meaningless or non-goal-directed) body movement. However, this notion is not supported by the analysis of infants' looking time to the video presentations. A recent study by Thompson and Russell (2004) provided some support for this notion. Using a "ghost" condition, they found that an effective mechanical operation of the apparatus without a human agent (e.g., a toy was brought into the reaching space when the cloth on which the toy was placed moved forward) was sufficient for infants to perform the target action as successfully as children who saw a human actor demonstrate an effective solution. In the current study, infants produced fewer target actions from seeing the body movements, but they did handle the objects instead of mimicking the demonstrator's gestures. It remains an open question as to whether infants this young could make sense of the videotaped gestures of the model manipulating novel objects.

The effects of seeing the object movements are likely to be a mechanism that Whiten and colleagues (Custance et al., 1999; Whiten et al., 2004) called "object movement reenactment." Recall that the end state was presented in both the body movement and object movement conditions. Why were the infants in the latter condition more likely to reproduce the outcome? An intuitive explanation is that they exhibited a preference for copying object movements. It might be that the spatial transformation of the object set was more likely to direct infants' attention to the end result than was the spatial transformation of the hands. The end state provided some information about how different parts of the object could be connected or configured in a certain way. Thus, exposure to object movement (but not to body movement) may enhance infants' tendency to realize the end state. It is tempting to generalize this hypothesis to the similar rate of target production in the full demonstration condition. Nevertheless, the strategies characteristic of infants in the full demonstration and object movement conditions were not equally efficient; therefore, it is unlikely that the strategy for producing the target action induced by the full demonstration model is due solely to the object movement component.

Finally, we turn to the item effects. The pattern of rates produced by the full demonstration model was not entirely consistent with that produced by the Experiment 1 video. As shown in Tables 1 and 3, in Experiment 2 the rates of reproductions with the dumbbell by the full demonstration video were 20% at the first act and 30% in the 20-s response period, compared with 40 and 70%, respectively, by the Experiment 1 video. One possibility is that the original clips involved a transition in which the actor restored the end state to the initial state to start a second demonstration (e.g., put the two cubes back to pull the dumbbell apart again), whereas in Experiment 2 this transition was cut off. This alteration was made to make task-irrelevant information the same across the four conditions. It might be that the original clips provided more information about object and body motions than did the current clips. Nevertheless, this interpretation cannot generalize to the high rates of reproductions with the prong/loop and cylinder/beads, which were 60 and 90% at the first act, respectively, by the full demonstration model in the current study, compared with 20 and 70%, respectively, by the Experiment 1 video. In addition, the low rate of reproductions with the dowel/square was found in both Experiments 1 and 2. Note that 50 to 90% of the infants' first acts involved either manipulating a demonstrator-inconsistent part of this object set (i.e., the dowel) or handling both the square and dowel (Table 2). This could be due to a containment affordance from the elevated strips glued along two edges of the square; a review of the tapes showed that, overall, 38% of the infants attempted to deposit the base onto the square at least once during the 20-s response period. Alternatively, a variety of influences (e.g., the specific characteristics of the sample, the specific constraints of the two-dimensional demonstration) might contribute to the item differences but could not be evaluated in the current study.

Experiment 3

In Experiment 2, infants produced the target action equally frequently after observing either the full demonstration video or the object movement video, and performance was much less successful following the body movement video. These findings imply that the central body movements were neither necessary nor sufficient for infants this young to produce the target action. Seeing the end state as a sufficient component could also be ruled out given that it was included in the body movement condition. However, it remains to be shown whether seeing the end state was a necessary component of the object movement condition. One parsimonious explanation is that only exposure to object movement would be sufficient to induce production of the target action through affordance learning. The purpose of Experiment 3 was to investigate whether object movement alone (affordance learning) or object movement plus end state (object movement reenactment) was critical to the effect of the object movement video observed in Experiment 2.

To this end, we devised one additional video to remove the end state component. This novel video consisted of an initial state and a transformation phase. The transformation phase recorded the object movement path involved in producing the target action but, unlike the object movement video in Experiment 2, never arrived at the end point where the object set's configuration was complete. To fulfill such a design, we modified the prerecorded videotape that closely mimicked Meltzoff's (1995) behavioral reenactment procedure. Following the procedure used in Experiment 2, we blocked out the torso and hands of the demonstrator to make body-based information unavailable in the transformation phase. Thus, following the initial state, infants saw only the object movements of an unsuccessful transformation in which the end state was never witnessed ("failed attempts"). The affordance learning hypothesis predicted that infants would be as likely to reproduce the end state of the target action after observing the object movement (failed attempt) video as they were after observing the object movement video used in Experiment 2.

Method

Participants

A total of 20 infants (7 boys and 13 girls, mean age = 17.2 months, $SD = 0.8$) participated in Experiment 3. An additional 4 infants were tested but not included in the final sample due to failure to attend to the video (3) or procedural error (1).

Apparatus, test situation, and procedure

The test objects and test situation were identical to those used in Experiments 1 and 2. All participants were tested individually at a laboratory of the department.

The experimental design included two conditions: object movement and object movement (failed attempt). Infants were randomly assigned to either condition. In the object movement condition, we replicated the clips that had been presented in the object movement condition in Experiment 2. In the object movement (failed attempt) condition, there were five digitally modified clips of the videotaped demonstrations based on Meltzoff's (1995) behavioral reenactment procedure. Following a procedure similar to that used in Experiment 2, we blocked out the presence of the demonstrator. Each clip consisted of a 10-s demonstration repeated twice. As before, a cartoon shot and a children's song were recorded for 10 s at the beginning. The initial state and transformation phase lasted 3 s and approximately 7 s, respectively. The initial state was a replicated component of the object movement video. The transformation recorded only the object movement component of an unsuccessful transformation in which the end state was never shown. For example, the stick rose up, moved toward the box, and fell down on the top of the box slightly away from the button (for a frame sample, see Fig. 1). The failed attempt object movement was modeled three times.

Scoring

The scoring procedure and behavioral definitions were identical to those employed in Experiment 2. In addition, we scored whether a failed attempt was reproduced as the child's first act. The criteria for scoring failed attempts followed those described by Huang and colleagues (2002, Appendix A). The first author and a second rater who was familiar with the scoring system scored all test sessions from the videotapes independently. Interrater reliability was 100% ($k = 1.0$) for target actions and failed attempts at the first act, 99% ($k = .98$) for target actions in the 20-s response period, and 94% ($k = .85$) for first-touched object parts.

Results

Mean target actions produced at the first act and in the 20-s response period can be seen in Tables 1 and 3. A mixed-model ANOVA on the rate of target production at the first act showed no significant effects of item, $F(4, 72) < 1$, or condition, $F(1, 18) < 1$. Very few infants reproduced the failed attempts as their first act. Mean numbers of failed attempts reproduced at the first act (and standard deviations) were as follows: object movement, .08 (.14); and object movement (failed attempt), .06 (.10). Mean percentages of time spent watching the monitor across the five video presentations (and standard deviations) were as follows: object movement, .85 (.08); object movement (failed attempt), .77 (.09). A two-tailed t test showed that infants attended more in the object movement condition than in the object movement (failed attempt) condition, $t(18) = 2.16$, $p = .044$.

Table 2 gives mean numbers of object parts that infants first touched. All infants were ready to interact with each item as their first act. Two-tailed t tests showed that there was no significant difference either in the mean number of first-touched object parts that were demonstrator consistent, $t(18) < 1$, or in the mean number of first-touched object parts that were demonstrator inconsistent, $t(18) = 1.00$, $p = .331$.

Similar to the first act analysis, there were neither significant effects of item, $F(4, 72) = 1.75$, $p = .148$, nor significant effects of condition, $F(1, 18) < 1$, in the rate of target production in the 20-s response period.

However, inspection of the means in Tables 1 and 3 shows that the overall rates of target production at the first act in Experiment 3 were numerically lower than those in the full demonstration condition (Experiment 2). Therefore, cross-experiment comparisons were made, taking into account both the full demonstration and baseline conditions from Experiment 2. These data were reanalyzed using one-way ANOVAs. There was a significant difference in the rate of target production at the first act, $F(3, 36) = 9.92$, $p < .001$, and in the 20-s response period, $F(3, 36) = 11.10$, $p < .001$. Post hoc comparisons using Bonferroni tests revealed that infants in the object movement, object movement (failed attempt), and full demonstration (Experiment 2) conditions did not differ from each other and that each group produced significantly more target actions than did infants in the baseline condition (Experiment 2) both at the first act ($p = .005$, $p = .02$, and $p < .001$, respectively) and in the 20-s response period ($p < .001$, $p = .001$, and $p < .001$, respectively). There also was a marginally significant difference in the mean number of nontarget actions before target production in the 20-s response period, $F(3,31) = 2.74$, $p = .06$. Follow-up Bonferroni tests revealed a significant difference in only one pair of groups; that is, the infants in the baseline condition (Experiment 2) produced more nontarget acts than did those in the full demonstration condition (Experiment 2) ($p = .05$).

Discussion

Experiment 3 replicated and extended the results of Experiment 2. The object movements extracted from the failed attempt model induced production of the target action as efficiently as did the object movements that led to the consummated target action.[2] The relatively low percentage of total looking time did not appear to affect efficient performance in the object movement (failed attempt) condition. It is likely that infants were more distracted by repetition in this condition given that the failed attempt object movement was modeled three times within one demonstration phase, compared with the "successful" object movement modeled only once. Remember that the end state was not observable in the object movement (failed attempt) condition. This suggests that seeing the end state is not necessary for producing the target action in the object movement condition. The current findings provide some support for Huang and colleagues' (2002) proposal that the object movement component of the behavioral reenactment procedure was sufficient for detecting key affordances between objects. Because the model's body movements were not available from the object movement (failed attempt) condition, it appears that attribution of intention to an agent need not be particularly reserved for the behavioral reenactment data. Nonetheless, the tendency to exploit the failed attempt object movements to emulate the target action instead of a mere copy of the observed event is striking.

Because only information about object movement is sufficient, infants' performance in both the object movement and object movement (failed attempt) conditions may well be interpreted as affordance learning. It seems that infants in these two conditions produced the target action in a somewhat indirect way. When compared with the baseline group (Experiment 2), only the strategy of the infants from the full demonstration condition (Experiment 2) was characterized by infrequency of nontarget actions. It is conceivable that the two other conditions might require infants to infer the key affordance rather than simply observe it as in the full demonstration condition. What were the main processes involved in the full demonstration condition? We suggest that high performance in this condition was perhaps due to a variety of social learning processes. For example, the availability of both the object movement and body movement components might have induced a process of stimulus enhancement that increased the likelihood that infants initially approached the relevant part of the

[2] An exceptional case was the dumbbell. None of the infants in the object movement (failed attempt) condition pulled this object off successfully at the first act. Note that the dumbbell remained whole in this clip, aside from it rising off the table and moving in the air. Thus, it is possible that information about potential affordances was reduced by the lack of observable evidence that the object set contained separable parts.

object. At the current time, it is not clear whether the infant must relate both components to the initial state or end state to achieve such high performance. Additional studies would be required for ruling out the combined effects of emulation learning, stimulus enhancement, mimicry, and goal-directed intention reading.

General discussion

The current findings show that object movement was a necessary and sufficient component of the videotaped demonstration to effect behavioral replication. Object movement reenactment and affordance learning offer two potential emulation mechanisms for the social learning of simple actions on objects during infancy.

However, the current data do not confirm that object-based emulation was the only responsible mechanism in the full demonstration condition. First, infants in the full demonstration and object movement conditions adopted different performance strategies in that the former condition was not likely to encourage infants to initially touch demonstrator-inconsistent parts of the object sets and produced fewer nontarget actions before succeeding in the response period, compared with infants in the baseline condition. With the benefit of observing the model interact with the objects, it appears that infants in the full demonstration condition more readily oriented to the target-relevant parts of the objects.

Some readers might be skeptical and argue that the videotaped model was inherently biased toward producing more object-based processing than person-based processing. After all, an action normally observed in a modeled response is not segregated (so far as we know) into the object or body movement pattern in the real situation. Indeed, the stimulus displays in this study were designed for these very reasons. Given the paucity of procedures that discriminate emulation and imitation, we contend that this method provides new insights into the key distinctions between emulation and what was once thought to have been imitation. Want and Harris (2002) argued that complex tasks (their Category 3) are necessary to distinguish emulation from imitation because both processes frequently result in the same actions being produced when simple actions (their Category 2) are modeled. We suggest, however, that simple actions also deserve careful investigation. Certain neurologically impaired patients have difficulty in producing pantomime gestures associated with objects or tools, even though the gestures involve very simple actions on familiar objects such as combing with a comb and pounding with a hammer (Dewey, 1991; Goldenberg & Hagmann, 1998; Renzi & Luchelli, 1988).

Why were infants much less successful when only body-based information was presented? The inferior performance could not be due to difficulty in remembering the movable part of the object that infants had already seen from the initial state given the 17-month-olds' capacities to register object permanence and a very short duration of disappearance involved in the transformation. The inefficiency of the body movement was not likely due solely to the inability to take information from two-dimensional images because infants in the full demonstration, object movement, and object movement (failed attempt) conditions benefited from watching the video.

Similarly, the inefficiency could not be due only to lacking information about the object's functionality because the infants were equally exposed to the initial state and end state that permits affordance detection from the object's end configuration. It is likely that the body movement pattern was less salient and perhaps less interesting than the object movement pattern, but this remains an open question.

One possible explanation for this might be that infants did not encode the observed motor movements as object directed. In the body movement condition, infants were actually presented with virtual pantomimes of object use. The task required them to interpret the pantomime during temporary disappearance of the movable object part. This appears to require an ability to infer the functionality of motor movements. Previous studies have shown that by 5 years of age, children already exhibit mastery of comprehending and performing pantomime gestures with imagined objects (Boyatzis & Watson, 1993; O'Reilly, 1995). It is conceivable that in the body movement condition, the movements of the hand(s) manipulating the objects have not been conventionalized, thereby increasing the novelty of the task.

Why were infants more successful in the full demonstration and object movement conditions? One possible explanation is that the two-dimensional nature of object movement is perceptually more discriminating than that of body movement. In the body movement condition, the model's hands recorded across clips were similar. Sensitivity to finger configuration and hand shape appears to be necessary for infants to encode the observed motor action. In contrast, in the full demonstration or object movement condition, the video image involved a distinct object part in motion. The object parts observed across clips differed from each other. Such a discriminating nature may have enabled infants to conduct their own visual exploration of the object despite its two-dimensionality.

The pantomime-based view tempts us to interpret the inefficiency of the body movement in terms of failure to use a strategy of mimicking. If this interpretation is accepted, the current findings may reveal the dissociation between mimicry and emulation in the development of social learning of simple actions on objects. We conjecture that emulation learning possibilities present a range of strategies that infants initially adopted and that mimicry is mastered later when action perception becomes differentiated with more sensitivity to bodily motions. Nevertheless, we cannot rule out the possibility that stimulus novelty prevented infants from using the mimicry strategy in the body movement condition. Note that infants in the live condition (Experiment 1) were more successful than infants who relied on the videotaped demonstrations (Experiments 2 and 3), albeit nonsignificantly. A more likely explanation, thus, is that performance was less efficient in the videotaped conditions due to no direct experience of the model's bodily actions.

The pattern of current findings is not entirely consistent with the hypothesis of Want and Harris (2002) that there is a developmental progression from mimicry to imitation and then to goal emulation. In addition to no indication of a strategy that came close to mimicry, our results show that some primitive forms of social learning, such as object movement reenactment and affordance learning, might well be at work during the second year of life. Could changes in hand position have encouraged infants to detect the model's goal state (goal emulation) from seeing the initial and end states? We suggest that the influence of the model's response topography, if any, is limited. If changes in hand position had been a key component, performance should have been much worse in the object movement (failed attempt) condition in comparison with that in the full demonstration and object movement conditions.

The current results also challenge goal emulation as an explanation for the behavioral reenactment data (Meltzoff, 1995). In the object movement (failed attempt) condition, infants successfully used the observed object movements to infer the target state that the model presumably intended but failed to achieve. A radical interpretation of this finding might be that infants visually explore dynamic affordances of objects even if there is no apparent agent (cf. Thompson & Russell, 2004). This view is inconsistent with the intentionality-based interpretation that infants see the body movements during failed attempts as directed to some certain goal state. Indeed, body movement is not the only cue on which infants can rely to learn about others' intended actions. In everyday situations, infants read intentions from a variety of contextual cues relevant to the social learning of actions on objects (Call and Carpenter, 2002; Carpenter et al., 2002). An interpretive problem with the behavioral reenactment procedure is that imitation is initially reserved for an intended subsequent but unobservable outcome. Failure to recruit copying body movements as the central requirement for imitation could lead to conflation of a model's goal with the effect of the model's action (Heyes & Ray, 2002). Careful delineation of mimicry will set up a way of guarding against alternative emulation learning interpretations of infants' responses for the behavioral reenactment paradigm.

However, the current study does not allow us to eliminate the hypothesis that current evidence of emulation is context specific. It might be that simple actions directly induce object affordances, thereby detracting attention to body movement. Bauer and Kleinknecht (2002) reported findings relevant to this hypothesis (see also Harnick, 1978). Reanalyzing the data from the study of Bauer (1992, Experiment 2), Bauer and Kleinknecht (2002) found that 20-month-olds differentially copied the demonstration according to task demands. In a two-step task, the infants tended to consistently mimic or emulate the event sequences through the trials. In a more difficult three-step task, they were likely to use combined strategies of emulation and mimicry. A theoretical concern as to whether the dissociation between mimicry and emulation is reliant solely on age-related mechanisms or on other context-specific factors can be raised here (Want & Harris, 2002).

An interesting area for future research would be to determine whether task and age variables impose constraints on social learning of certain types. To clarify whether encoding of body movement is related to cognitive mechanisms, one will need an experimental design that includes older children. To evaluate interactions between task type and mimicry will require a different type of experiment in which the target action can be replicated only through copying the model's response topography. For example, while the object is not allowed to move, children see only the model's bodily parts move to trigger an observable outcome from the object (for a notable example, see Gergely, Bekkering, & Király, 2002). In future studies, it would be interesting to find out whether the lack of mimicry in children in the current study was due to task demands, developmental differences, or any possible psychological mechanisms such as reading goals and gesture pantomime.

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