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Infants' Behavioral Reenactment of "Failed Attempts": Exploring the Roles of Emulation Learning, Stimulus Enhancement, and Understanding of Intentions

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Two studies were conducted to examine whether infants' reenactment of intended but unconsummated acts in A. N. Meltzoff's (1995) failed-attempt paradigm is due to reading the adult's underlying intention or to the effects of nonimitative social learning processes. Two novel conditions that emphasized the object affordances and the spatial contiguity of the object sets were devised. When infants' first actions only were counted, infants who observed the full-demonstration model produced more target acts. When all target acts produced within the 20-s response period were counted, infants in the emulation-learning and spatial contiguity conditions produced as many target acts as infants in the full-demonstration and failed-attempt conditions. This pattern of findings suggests that nonimitative social learning processes may influence infants' response in the behavioral reenactment paradigm.

Contemporary studies of imitation in infancy have examined the procedures necessary for specifying infant behavior as imitation (Jones, 1996; Meltzoff & Moore, 1977, 1983a, 1983b), the social roots of imitation (Meltzoff & Gopnik, 1993; Trevarthen, Kokkinaki, & Fiamenghi, 1999; Uzgiris, 1981), the cognitive significance and development of imitation (Abravanel & Gingold, 1985; Meltzoff, 1988a, 1988b), and the phylogeny of imitation across human and nonhuman primates (Tomasello, Savage-Rumbaugh, & Kruger, 1993; Whiten & Custance, 1996). It has been demonstrated that an infant becomes capable of imitating novel acts on objects between 9 and 12 months of age (Meltzoff, 1988a, 1988b; Piaget, 1951/1962). This is also the period during which joint attention and social referencing behaviors, which involve infants' sharing attention or an attitude toward an object with another individual, emerge (Bakerman & Adamson, 1984; Trevarthen & Hubley, 1978; see Tomasello, 1999; for a review). These behaviors have been interpreted as early evidence of infants' understanding of intentions (Baron-Cohen, 1991; Carpenter, Nagell, & Tomasello, 1998; Tomasello, 1995) and even as precursors of a theory of mind (Bretherton, 1991; Charman, 2000; Charman et al., 2000). Thus, there is a convergence in terms of age onset between infants' abilities to imitate object-related behaviors and their early social understanding.

Meltzoff (1995) made the first attempt to investigate directly the connections between infant imitation and the concept of intention. In Meltzoff's study, a novel demonstration (intention) condition was designed to explore infants' understanding of the intentional actions of others through imitation of actions on objects. The demonstrator was seen to attempt, but fail, to bring about certain target acts on objects. For example, the demonstrator attempted three times to put a loop over a protruding prong but "accidentally" missed the tip of the prong so that the loop dropped to the table. Meltzoff found that 18-month-old infants produced target acts as frequently following observation of these "failed attempts" as they did following observation of the demonstrator successfully completing the target actions. Meltzoff concluded that 18-month-old infants infer an adult's intended but unconsummated target or goal. That is, they reenact not simply what they observe the adult do but rather what the adult intended to do. In a second experiment, infants were shown a mechanical device with two pincers that mimicked the way the demonstrator had acted on a dumbbell-shaped toy in the failed-attempt display: Pincers grasped the dumbbell on the two ends and pulled them outward, and one pincer slipped off one of the two ends (Meltzoff, 1995). After watching the unsuccessful acts demonstrated by the mechanical device, infants did not pull the dumbbell apart as often as they did after watching the same action demonstrated by a human actor. Meltzoff suggested that 18-month-olds are able to situate people, but not inanimate objects, within a "psychological framework" that differentiates the surface behavior of people from a deeper level of behavior involving underlying goals and intentions.

Bellagamba and Tomasello (1999) replicated the finding for 18-month-olds but, in contrast, found that 12-month-olds seldom produced target acts following observation of failed attempts. Further, Bellagamba and Tomasello found that following exposure to the end state only (e.g., the separated two halves of the dumbbell

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placed on the table in front of the infant), neither 12- nor 18-month-olds reproduced target acts as frequently as they did following observation of failed attempts or of completed target acts.

Thus, Meltzoff (1995) and Bellagamba and Tomasello (1999) concurred that the production of target acts by 18-month-old infants following a failed-attempt demonstration is evidence that the infants inferred the adult's underlying but unconsummated intentions. However, a more cautious analysis of the responses of infants in the behavioral reenactment paradigm may yield a different conclusion. Intention is unobservable, and the conclusion that a behavior involves attribution of intention can only be confirmed by eliminating the possibility that it is based on other forms of social learning (Heyes, 1996, 2001). Want and Harris (2002) reviewed the potential for nonimitative social learning processes (including local or stimulus enhancement, mimicry, and emulation learning) to account for many of the findings in the human infant literature (see also Carpenter & Call, 2002; Charman & Huang, 2002; Heyes, 2001; Heyes & Ray, 2002; Whiten, 2002). In the present study, we aimed to bring such a critique to bear on the behavioral reenactment procedure because, according to the authors of studies using this procedure, it provides the most compelling evidence of infants' understanding of intentions (Bellagamba & Tomasello, 1999; Meltzoff, 1995; see also Aldridge, Stone, Sweeney, & Bower, 2000).

Thorpe (1963) defined imitation as "the copying of a novel or otherwise improbable act or utterance, or some act for which there is clearly no instinctive tendency" (p. 122). That is, not only does an imitator not merely copy a specific act performed by a model but the copied act should also not be part of the imitator's current behavioral repertoire. Although there is some debate in the literature on social learning in animals (Heyes, 1996; Whiten & Custance, 1996) about whether a behavior can be entirely novel, a more generous criterion for determining behavioral novelty has been adopted in developmental studies of infant imitation. A behavior that infants imitate is novel in the sense that infants do not produce it on their own in the absence of the demonstrated model. Infants' production of the target acts after watching the failed-attempt display in Meltzoff's (1995) study cannot be called imitation by Thorpe's (1963) definition because infants did not reproduce the demonstrator's failed attempts. That is, there was a lack of behavioral convergence between the infants' response and the demonstrator's model. However, the target acts involved are novel in the sense that the infants in both the baseline and adult-manipulation control groups generated such acts relatively infrequently.

Several authors have drawn attention to the fact that imitation is a matter of degree; there is not necessarily an exact match between the imitator's and the model's behavior (Moerk, 1989; Snow, 1981; Whiten & Ham, 1992). According to Moerk (1989), reduced imitation often indicates children's difficulty in handling and reproducing all the inputs from the demonstration, and expanded imitation implies that the inputs are processed at more advanced levels. Thus, infants' performance of the target acts in response to the failed-attempt model may be viewed as expanded imitation, with new elements independently contributed by the infant. One candidate for this additional element, consistent with the interpretation of Meltzoff (1995) and Bellagamba and Tomasello (1999), is the adult's unconsummated intention to produce the target act. However, an alternative possibility is that the additional element involves other aspects of the social learning situation. For example, emulation learning in which an individual learns about the end result of a sequence of actions from knowledge of the causal structure of the demonstrated sequence might provide the additional element that induces the infant to produce an expanded match (Tomasello, 1996). To put the question simply, if Meltzoff's (1995) findings entail expanded imitation, it is important to clarify whether the infant's additions are attributable to an understanding of the model's intentions or to an understanding of the causal structure of the task. Heyes and Ray (2002) referred to this distinction as "intention-sensitive imitation" versus "outcome-sensitive imitation."

Several types of nonimitative learning have been identified in the animal kingdom (Galef, 1988; Heyes, 1996; Thorpe, 1963; Whiten & Ham, 1992). Tomasello (1996) pointed out three types of social learning that often lead to a behavioral correspondence between an observer and a model but are distinct from the phenomenon of imitation: local or stimulus enhancement, emulation learning, and mimicking. Behavioral reproduction of a modeled action may occur when observation of the manipulations of the demonstrator draws an individual's attention to particular environmental locations (local enhancement) or relevant parts of objects (stimulus enhancement). Thus, the individual learns to adjust to specific environmental features without learning about the observed actions (Tomasello, 1996; Whiten & Ham, 1992). Stimulus enhancement may provoke an individual to react to a specific part of an object highlighted by the behavior of others. In contrast, in imitation, an individual reproduces the behavior of a model as a result of learning something about the behavior's intrinsic form, such as the movement topography or the intentional relation between the model's goal and the desired outcome (Barresi & Moore, 1996; Call & Carpenter, in press; Custance, Whiten, & Fredman, 1999; Tomasello, 1996).

In Meltzoff's (1995) study, an adult-manipulation control condition was designed to control for the possibility that infants might tend to play with the objects if they saw the adult manipulate them and that this alone would induce them to produce the target acts. In this control condition, the experimenter acted on the test objects for the same length of time as in the demonstration conditions but without producing the target acts or the failed attempts. Thus, the adult-manipulation control condition could be sufficient to assess whether the infant's performance on target acts was based on stimulus enhancement. However, in the failed-attempt condition, the experimenter did not merely handle the target-act-relevant parts of the objects but deliberately moved them so that they were spatially contiguous with one another. For example, a string of beads fell to the table beside a cylinder without touching it in the adult-manipulation control condition, whereas the beads crossed the upper rim of the cylinder each time the experimenter attempted but failed to deposit them in the cylinder in the failed-attempt condition. It may be that the infants watching the failed attempts put the beads into the cylinder more often than they did in the adult-manipulation control condition because they saw the beads and the cylinder touch each other in the experimenter's failed attempts. In the failed-attempt condition, the spatial contiguity of the target-relevant parts of the objects may provide sufficient stimulus enhancement to induce infants to perform the target acts.

According to Tomasello (1990, 1996), emulation learning occurs when an individual, through observation, learns something about the changes of state in the environment (e.g., objects) as a result of the behavior of the model but not about the model's behavior or behavioral strategy (see Wood, 1989). Whiten and Custance (1996) described emulation as a cognitive ability to reproduce an outcome by intelligently selecting and extracting useful information from the demonstration. This may involve learning neither the model's behavior nor even the model's goal. However, an observer might reproduce the end result via their own method with an understanding that the model held a goal toward such an outcome ("goal emulation"; Whiten & Ham, 1992). Alternatively, an observer could derive the action information required for reproducing the end result by himself or herself without explicitly encoding and reproducing the actions demonstrated from seeing the object movement ("object movement reenactment", Custance et al., 1999). A further possibility is that an observer derives information about the target acts by observing the terminal state of the object that specifies the object affordances and that this information is sufficient for the observer to produce the target act ("affordance learning"). In some circumstances, emulation learning presents an advanced cognitive strategy compared with imitation. For example, knowing the affordances, or typical uses, of objects allows children to incorporate this knowledge into their own attempts to find out how novel objects can be used.

In Meltzoff's (1995) study, the pattern of the object movements characterizing the failed attempts was more similar to the pattern presented in the full-demonstration target display than to the pattern of the object movements demonstrated in the adult-manipulation control condition. For example, with the plastic square and the dowel, the square was moved along the sides of the wooden base in a vertical position in the adult-manipulation control condition. In contrast, in the failed-attempt demonstration, the hole of the square overshot the dowel as a result of the square's sloping down on the base almost horizontally. In the failed-attempt condition, but not the adult-manipulation condition, the movement closely resembled the intended target act. Thus, it is possible that infants may have learned the dynamic affordances of the objects from seeing the movements demonstrated in the failed-attempt displays, and that knowledge may have led to their performance of the target acts. In other words, observation of the demonstrated failed attempts might have evoked the infants' knowledge of the causal structure of the test materials (what end points the sequence of movements could lead to) and provided an object movement pattern to emulate. This may have resulted in the infants' producing the target acts more frequently than they did after watching the adult-manipulation control acts that were dissimilar and irrelevant to the target acts.

In Meltzoff's (1988b) study of deferred infant imitation, a control condition was used to assess the possibility of emulation learning. In this condition, the experimenter demonstrated for the infants the results of the target acts by means of surreptitious non-target-relevant actions. Although the 9-month-olds in this control condition did not produce the target acts as frequently as they did by observing the target display, 18-month-olds may be more likely to use the strategy of emulation learning. Bellagamba and Tomasello's (1999) finding that observation of the end state only did not induce 12- or 18-month-olds to reproduce the target acts is consistent with Meltzoff's (1988b) results. However, in Bellagamba and Tomasello's study, infants did not have access to the initial states of the objects. One possibility is that exposure to both the initial and the end-state displays might provide sufficient cues for emulation learning to enable 18-month-old infants to produce the target acts.

The aim of the present study was to extend Meltzoff's (1995) failed-attempt paradigm to include additional controls in order to examine the role of emulation learning and stimulus enhancement in infants' reproduction of target acts following the demonstration of failed attempts. In Experiment 1, we replicated the three conditions in Meltzoff's (1995) study: Demonstration (target), Demonstration (intention, or "failed-attempt"), and Control (adult manipulation). In addition, in a novel emulation-learning condition, infants were exposed to the initial and end states of the target display but not the experimenter's manipulations of the test objects (which were occluded by a screen). The critical question was whether infants would produce the target acts in the emulation-learning condition as frequently as they would after observing the target or the failed-attempt displays. In Experiment 2, we extended the design by introducing a second new condition, the spatial contiguity condition, to examine whether infants' performance of target acts after watching the failed-attempt display was due to a form of stimulus enhancement. The critical question was whether, following observation of the transitional states when the target-relevant parts of the object sets were spatially contiguous to each other (but neither the consummated target act as seen in the full-demonstration condition nor the unconsummated failed-attempt display was seen), infants would reproduce the target acts as frequently as they would after observing the target or the failed-attempt displays. Our hypothesis was that if the role of emulation learning and stimulus enhancement was to be ruled out, infants should produce more target acts in the failed-attempt condition than in the novel emulation-learning (Experiment 1) and spatial contiguity (Experiment 2) conditions.

Two methodological improvements to the behavioral reenactment paradigm were introduced. First, in addition to recording whether infants produced the target acts within the 20-s response period (as in Meltzoff, 1995, and Bellagamba & Tomasello, 1999), we independently scored the first action that the infants produced on the objects. We did so because infants commonly produced a number of different actions on the objects within the 20-s response period. Direct imitation of a modeled action should result in infants' reproducing the demonstrated action as their first (and not a subsequent) response. Second, each action produced was scored as one of a behaviorally defined set of actions that included reproduction of the failed attempts, the adult-manipulation control actions, the spatial contiguity action, other actions, as well as reproduction of the target acts for each object set. This scoring procedure contrasts with that in Meltzoff's (1995) and Bellagamba and Tomasello's (1999) studies, which counted only the number of target acts, and adult-manipulation control acts, produced by each infant in each condition, respectively. The present scoring was used (a) to examine whether infants reproduced (imitated) the modeled actions following demonstrations that did not lead to the consummated target act and (b) to avoid conflating such actions (e.g., reproduction of the failed-attempt and spatial contiguity displays) with target actions.

Experiment 1

Method

Participants

Participants were forty 19-month-old infants (24 boys and 16 girls; mean age = 19.1 months, *SD* = 1.5) recruited from a number of playgroups in London, England. The sample was 65% White Caucasian, 17.5% Asian, 2.5% African/Caribbean, and 15% mixed ethnicity.

Test Situation

The test sessions were conducted in a quiet corner in the playgroup (*n* = 27), at home (*n* = 12), or at the laboratory of a university psychology department (*n* = 1). During the session, the infant was seated in front of a small table opposite the experimenter. The parent or caregiver sat behind the infant. If the infant would not sit at the table, he or she sat on the floor facing the experimenter. A camcorder fixed on a tripod stood behind and to the left of the experimenter, focusing on the head, hands, and torso of the infant and the surface of the table. The session started with joint play with rubber animals or a picture book, and once the infant was settled, the toys were withdrawn and the first test object was presented.

Test Materials

The materials comprised replicas of the five objects used in Meltzoff's (1995) study (see Meltzoff, 1995, p. 840 for diagrams).

Dumbbell. The first object was a dumbbell-shaped toy that could be pulled apart and put back together again. It consisted of two wooden cubes, each with a plastic tube extending from it on one side. The two cubes could be connected into one piece by fitting one tube snugly inside the other.

Box and stick. The second object consisted of a rectangular block of wood (the stick) and a box. The front surface of the box tilted at an angle of 30° off the table. A slightly recessed rectangular button, which activated a buzzer inside the box, lay on the right half of the front surface. The end of the wooden stick could fit inside the recess to activate the buzzer.

Prong and loop. The third object consisted of a rubber loop and a vertical rectangular board set on a wooden base. A plastic prong with a bulbous point protruded horizontally from the board at a position slightly beneath its upper edge.

Cylinder and beads. The fourth object consisted of a chain of purple beads, about 20 cm long when suspended, and a yellow cylinder.

Square and dowel. The fifth object consisted of a transparent plastic square and a wooden dowel. The dowel stood in the center of a wooden base plate. The plastic square had a round hole cut out of the center so that the dowel could pass through the hole when the square was put over the base.

Experimental Design

There were four conditions in the study: the full-demonstration, failed-attempt, emulation-learning, and adult-manipulation conditions. Except for the novel emulation-learning condition, the procedures of the other three conditions were identical to those described by Meltzoff (1995).

In the *full-demonstration* condition, the experimenter modeled a specific target act with each of the five objects. For each stimulus, the target act was repeated three times in approximately 20 s, and the object was then placed on the table or on the floor directly in front of the infant. For the dumbbell, the act demonstrated was picking it up by the wooden cubes and pulling outward with a definite movement so that the toy broke apart into two halves. The two halves were then reconnected and the action was repeated. For the box and stick, the act demonstrated was picking up the stick and using it to push in the button, which then activated the buzzer inside the box. For the prong and loop, the act demonstrated was raising the loop up to the prong and draping it over so that the loop rested on the prong. For the beads and cylinder, the act demonstrated was raising the chain of beads up over the opening of the cylinder and then lowering them into the opening so that they were deposited on the bottom of the cylinder. For the square and dowel, the act demonstrated was picking up the plastic square and putting the hole over the dowel in the center of the wooden base plate.

In the *failed-attempt* condition, the experimenter did not demonstrate the target acts. Instead, the experimenter was seen by the infant as trying but failing to achieve the target acts. The failed attempt to produce the target act was modeled three times in approximately 20 s. The object was then placed in front of the infant. For the dumbbell, the experimenter picked it up by the two wooden cubes and appeared to pull the ends outward, but on each occasion one hand slipped off one of the cubes as the experimenter tried (but failed) to pull the cubes outward. The direction of the hand slippage movement alternated from left, to right, and to left across the three attempts. For the box and stick, the experimenter picked up the stick and used it to try and push the button on the box, but on each occasion he missed the recess so that the stick touched down on the surface of the box slightly away from the recess. First the stick missed to the left of the recess, next it missed to the right, and finally it fell too high. For the prong and loop, the experimenter raised the loop, but as he approached the prong he inappropriately released it and the loop dropped to the table or the floor. First the loop was released to the left of the prong, next to the right, and finally below the prong. For the beads and cylinder, the experimenter raised the chain of beads and appeared to attempt to deposit them into the cylinder, lowering them so that the tip of the beads crossed the edge of the top lip of the cylinder. However, on each occasion he inappropriately released the beads so that they fell onto the table outside the cylinder. First, the chain was released to the left of the opening, next to the right, and finally in front of the cylinder. For the square and dowel, the experimenter picked up the plastic square and appeared to attempt to put it on the dowel. However, on each occasion the hole was not correctly aligned with the dowel, and the square ended up resting on the base at a tilt. First, the square missed to the left, next it missed to the right, and finally it rested in front of the dowel.

In the *emulation-learning* condition, the infant observed only the initial state and the end state of the target acts. First, the experimenter introduced the object on the table for 10 s. Then, a barrier made of cardboard was placed between the infant and the object. The experimenter then performed the target act unseen by the infant. After the target act was completed, the experimenter removed the cardboard, revealing the end state to the infant for 10 s. The barrier was placed between the infant and the object again, and the experimenter restored the object to its initial state unseen by the infant. Last, the barrier was withdrawn and the object was placed in front of the infant. As in the three other conditions, the whole demonstration lasted 20 s. Note that this condition differs from the three other conditions in that no manipulation of the object was seen by the infant. For the dumbbell, the initial state consisted of the two halves connected lying on the table. The end state consisted of the two halves of the dumbbell separated from each other. For the box and stick, the initial state consisted of the stick lying next to the box on the table. The end state consisted of the activation of the buzzer (for this object only, the barrier was not removed, and the infant did not see the buzzer on the box being activated with the stick). For the prong and loop, the initial state consisted of the loop lying on the table next to the board with the prong. The end state consisted of the loop resting on the prong. For the beads and cylinder, the initial state consisted of the beads lying on the table next to the cylinder. The end state consisted of the chain of beads deposited inside the cylinder (the cylinder was tilted toward the infant to ensure that the infant saw the beads resting on the base of the cylinder). For the square and dowel, the initial state consisted of the plastic square resting on the table beside the base with the dowel. The end state consisted of the square aligned over the base with the dowel protruding through the hole.

In the *adult-manipulation* condition, the demonstrator manipulated the test objects for the same length of time as in the full-demonstration and failed-attempt conditions, but neither the target acts nor the failed attempts were demonstrated. That is, different actions were modeled on the objects three times in the 20-s modeling period. The object was then placed in front of the infant. For the dumbbell, the experimenter picked up the object by the wooden cubes and pushed both hands inward. For the box and stick, the experimenter held the stick horizontally and moved it back and forth along the top surface of the box, with the tip of the stick passing next to and over the recessed button. First the stick started from the lower edge of the top, next it started from the left, and then it started from the right. For the prong and loop, the experimenter raised the loop up to the level of the prong, then slid it along the upper edge of the board past the prong, and released it when it reached the end. First the loop started from the left end of the upper edge, next it started from the right end, and then it was moved along the base supporting the board under the prong before being released. For the beads and cylinder, the experimenter raised the chain of beads and lowered them onto the table next to the cylinder. When they were resting half on the table, they were released and fell onto the table. First the chain fell to the left of the cylinder, next it fell to the right, and finally it was gathered in a loosely held fist and let fall onto the table to the left of the cylinder again. For the square and dowel, the experimenter held the square vertically so that it was standing upright and moved it along the wooden base plate that held the dowel. First the square was moved along the front edge of the base, second it was moved along the back edge, and third it was moved along the front edge again.

The participants were randomly assigned to one of the four conditions, which resulted in 10 children per group. The sequence of the five objects was counterbalanced within each condition. When the object was placed in front of the infant at the beginning of the 20-s response period, most children readily made contact with the objects placed in front of them. If the children did not touch the objects, the experimenter would call their names or say “Look!” to engage them, but he never used definite instructions such as “do what I do,” “copy me,” or “pull it out.” The experimenter did not give affective or linguistic cues during the modeling or response periods.

Scoring Criteria

The scoring strategy adopted in most research on imitation has been to record (a) a dichotomous yes/no response on the basis of whether the infant produces the target act within a specified response period (e.g., Devouche, 1998; Meltzoff, 1988a, 1988b, 1995) and (b) the latency of the production of the target act (e.g., Devouche, 1998; Meltzoff, 1995). Meltzoff (1995) and Bellagamba and Tomasello (1999) also scored reproductions of the adult-manipulation action within the response period.

In pilot work conducted for the current study, it was noted that some children produced several actions on the objects within a 20-s response period. When a target act was produced within the 20-s response period, it was not always the first action produced by the infant; sometimes it was the second or even the third action. In the hope that the sequence of actions might provide some insight into the behavioral strategies underlying an infant’s response, we decided to code both the first action produced as well as whether the target action was produced within the 20-s response period. Our rationale was that if an infant learned to perform the target act by imitation, he or she should have produced it as the first response (Whiten, Custance, Gomez, Teixidor, & Bard, 1996), with a relative infrequency of exploratory responses before it was produced. Further, we decided to code each action into one of five mutually exclusive categories, each with strict behavioral definitions: “target act,” “failed act,” “adult manipulation,” “other act,” and “no act.” This was done (a) to examine whether infants reproduced (imitated) the modeled actions following demonstrations that did not lead to the consummated target act and (b) to avoid conflating such actions (e.g., reproduction of the failed-attempt display) with target actions. If the children did not respond at all in the scoring period, it was coded as “no act.” The detailed scoring criteria are shown in Appendix A.

In addition, the following measures were also included in the analysis.

1. The latency for all target acts produced within the 20-s response period, timed from when the infant touched the object.

2. The part of the object set that the children touched first during the scoring period. We thought this measurement might be helpful in exploring whether how the children tended to manipulate a particular part of the object set depended on how they had observed the experimenter act on the object.

3. A separate code (“finger”) for a response involving the use of a finger to activate the buzzer in the object set of box and stick. This action was given a separate code because we felt that potentially valuable information would be lost by coding it as an “other” act. For the box and stick object set, the children only heard the beeping sound when the experimenter used the stick to push the button to activate the beeper in the box behind the screen. However, they did not see the experimenter make contact with the stick. Would infants be able to devise their own behavioral strategy to activate the beeper? That is, instead of using the stick, might they use a finger to push the recessed button and activate the buzzer?

Interrater Reliability

Chi-Tai Huang coded the infants’ responses to each of the five test objects from the videotapes. To assess interrater reliability, we had a colleague who was familiarized with the scoring system independently code 30% of the data (3 infants per condition). Reliability was calculated for the coding of the infants’ first acts as falling into one of the five mutually exclusive scoring categories and for the target acts produced within the 20-s response period. Agreement was high: For target acts produced in the 20-s response period, $\kappa = 1.0$; for first actions across the five mutually exclusive scoring categories, $\kappa = .78$.

Results

Two infants did not have a complete record of five response periods because of a faulty camcorder during the testing (1 infant’s response to the loop and prong in the full-demonstration group and 1 infant’s response to the square and dowel in the emulation-learning group). Therefore, proportions rather than frequencies were used in the analysis. Table 1 shows the number of children

Table 1
Number of Children Producing Target Acts in the 20-s Response Period and at First Actions as a Function of Group

Group	Number of target acts: 0	1	2	3	4	5
20-s response period						
Full demonstration[a]	0	0	1	3	4	2
Failed attempt	1	0	4	2	2	1
Emulation learning[a]	0	2	5	1	1	1
Adult manipulation	3	4	1	2	0	0
First action						
Full demonstration[a]	0	1	3	3	2	1
Failed attempt	1	2	7	0	0	0
Emulation learning[a]	1	6	2	1	0	0
Adult manipulation	6	2	2	0	0	0

[a] One trial was missing for 1 subject in the full-demonstration and emulation-learning groups.

producing target acts in the 20-s response period and at first action as a function of group (compare to Table 1 in Meltzoff, 1995, p. 842). Table 2 shows the proportion of children producing target acts, failed acts, adult-manipulations, other acts, and no acts as a function of group (compare to Table 2 in Meltzoff, 1995, p. 843 and to Table 1 in Bellagamba & Tomasello, 1999, p. 280). The data for target acts produced within the 20-s response period and for first action were entered into one-way analyses of variance (ANOVAs) with experimental condition as a between-subjects factor. Follow-up Tukey's honestly significant difference (HSD) tests were used to assess specific group differences.

There was a significant difference in the mean proportion of target acts produced during the 20-s response period, $F(3, 36) = 7.67$, $p < .01$. Follow-up Tukey's HSD tests showed that the infants in the full-demonstration, failed-attempt, and emulation-learning conditions did not differ in the proportion of target acts produced in the 20-s scoring period. However, infants in the full-demonstration and failed-attempt conditions produced more target acts in the 20-s response period than did infants in the adult-manipulation condition ($p < .01$ and $p < .05$, respectively), but no difference was found between the infants in the emulation-learning and adult-manipulation conditions. There was a significant difference in the mean proportion of target acts produced at the first action as a function of condition, $F(3, 36) = 11.74$, $p < .01$. Follow-up Tukey's HSD tests indicated that infants in the full-demonstration condition produced significantly more target acts at the first action than did infants in the failed-attempt ($p < .01$), emulation-learning ($p < .01$), and adult-manipulation ($p < .01$) conditions. The infants in the latter three conditions did not differ from each other.

The infants in the failed-attempt condition reproduced only 6% of the demonstrated failed attempts at first action. Similarly, the infants in the adult-manipulation condition reproduced only 6% of the demonstrated actions at first action. Further, children in the failed-attempt group were not more likely than the children in the three other groups to produce failed-attempt responses. Similarly, children in the adult-manipulation group were not more likely than the children in the three other groups to produce adult-manipulation responses. There was a significant difference in the proportion of "other" acts produced at first action as a function of condition, $F(3, 36) = 5.24$, $p < .01$. Pairwise comparisons showed that the infants in the full-demonstration condition produced fewer "other" acts at first action than did infants in the emulation-learning ($p = .05$) and adult-manipulation conditions ($p < .01$).

Table 3 shows the proportion of object parts the infants first touched, according to whether the touched parts were consistent with, or different from, the parts that the experimenter had first handled, and whether the infants started by touching more than one part or did not touch the object set at all. There was a significant effect of condition on the proportion of first-touched object parts that were consistent with those the experimenter had first touched, $F(3, 36) = 2.98$, $p < .05$. Pairwise comparisons with a Tukey's HSD test, however, did not show a significant difference between any pair of groups. There was a significant effect of condition on the proportion of first-touched object parts that were different from those the experimenter had first touched, $F(3, 36) = 3.19$, $p < .04$. Follow-up Tukey's HSD tests revealed a difference between only one pair of groups: The infants in the emulation-learning condition more often first touched parts of the objects different from the parts the experimenter touched than did the infants in the failed-attempt condition ($p < .03$).

The mean latencies to produce the target acts in the 20-s response period (and *SD*s) were as follows: full demonstration, 5.41 s (2.61); failed attempt, 5.91 s (2.27); emulation learning, 8.03 s (3.12); and adult manipulation, 10.91 s (5.06). A significant effect of condition was found, $F(3, 32) = 4.64$, $p < .01$. Pairwise comparisons showed that the infants in the adult-manipulation condition had a longer latency to produce target acts in the 20-s response period than did infants in the full-demonstration ($p < .01$) and failed-attempt conditions ($p < .05$).

Table 2
Proportion of Infants Producing Target Acts Within the 20-s Response Period as a Function of Group and the Proportion of Infants' Responses Falling Into Each of the Scoring Categories at First Action

	Full demonstration		Failed attempt		Emulation learning		Adult manipulation	
Action	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
20-s response period								
Target acts	.76	.18	.54	.28	.48	.25	.25	.23
First action								
Target acts	.60	.25	.32	.14	.26	.16	.12	.17
Failed attempt	.04	.08	.06	.13	.04	.08	.00	.00
Adult manipulation	.00	.00	.00	.00	.02	.06	.06	.10
Other acts	.37	.22	.58	.20	.62	.20	.74	.23
No acts	.00	.00	.04	.08	.00	.00	.03	.08
Finger[a]	.00	.00	.00	.00	.06	.10	.04	.08
Total	1.00		1.00		1.00		1.00	

[a] Proportion of infants activating the buzzer in the box and stick object set with their fingers.

Table 3
Proportion of Parts of Objects Infants First Touched in the Response Period

Condition	Part touched consistent with the demonstration		Part touched different from the demonstration		Touched more than one part		No response	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Full demonstration	.80	.21	.16	.16	.04	.08	.00	.00
Failed attempt	.82	.18	.06	.10	.08	.14	.04	.08
Emulation learning	.60	.23	.34	.27	.06	.13	.00	.00
Adult manipulation	.64	.20	.22	.26	.12	.14	.03	.08

Discussion

The findings of the present study are consistent with those of Meltzoff (1995) and Bellagamba and Tomasello (1999) in that there was no difference between the full-demonstration and failed-attempt groups in terms of target acts produced in the 20-s response period. However, the production of target acts in the 20-s response period was also similar for infants in the novel emulation-learning condition, in which the child did not see the experimenter manipulate the object. Does this present a challenge to the intentional interpretation of Meltzoff (1995) and Bellagamba and Tomasello (1999)?

The emulation-learning condition was designed to test whether infants might produce target acts as a result of their learning about the dynamic affordances of the objects. That is, exposure to the initial and the end states of the object sets might be sufficient for infants to emulate this transformation (Custance et al., 1999; Tomasello, 1990; Whiten & Ham, 1992). Under this interpretation, an explanation for the production of target acts following the failed-attempt display that is more parsimonious than the intentional one is possible. In the emulation-learning condition, emulation learning could occur by direct observation of the end state alone because this was related to the affordances of the objects (affordance learning; e.g., seeing the loop on the hook). Similarly, in the failed-attempt condition, emulation learning could occur by observation of the manipulation of the afforded target-relevant parts of the object set, despite the nonconsummation of the target acts. We use a “lean” definition of emulation which states that it can occur through direct observation of the object-afforded properties, in contrast to Tomasello’s (1990, 1996) definition. Thus, the infant is not required to infer the transformation that took the initial state into the final state. Relative to this noninferential kind of emulation learning, attribution of intention reading to the infant appears to be a less parsimonious explanation. It could be argued that the emulation-learning explanation is simpler than the intentional attribution explanation because it involves only first-order representation (of object properties), whereas the attributing of intentions involves both first-order representation (of body movements) and second-order representation (of the actor’s intentions) (Barresi & Moore, 1996). A similarly lean interpretation in terms of the Custance et al. (1999) “object movement reenactment model” could provide an alternative parsimonious explanation for production of target acts following the failed-attempt (but not the emulation-learning) display.

Another piece of evidence for emulation learning was the case of the infants in the emulation-learning and adult-manipulation conditions, some of whom efficiently used their fingers to activate the beeper in the object set of box and stick. At first action, no infants in the full-demonstration or failed-attempt conditions used this strategy. Their attention had already been cued to the close juxtaposition of the stick and the opening to the recessed buzzer. For infants in the emulation-learning and adult-manipulation conditions, who had not seen this juxtaposition, exposure to the acoustic affordance of an object, coupled with their prior experience of buzzers to be pushed, was sufficient for infants to invent their own behavioral strategy to reproduce the target act.

However, the findings of the present study appeared very different when only the first actions performed by the infants on the object sets were considered. At first action, the full-demonstration group produced target acts more frequently than the three other groups. If, in the failed-attempt condition, infants are inferring the experimenter’s unconsummated intentions and imitating them, then why did they not produce the target acts as their first action? One would expect the first act performed by a child to provide a more accurate reflection than subsequent acts of what the child has learned by observation of the model rather than through his or her own direct interactions with the test objects. Relevant to this point, infants who viewed the failed-attempt demonstration, in common with those in the emulation-learning and adult-manipulation conditions, produced more “other” acts than target acts as their first actions on the object sets. Might these be exploratory acts that allowed the infants to learn about the affordances of the objects to a sufficient degree that they then produced the target act as a subsequent action?

A different pattern was seen when the latencies to produce target acts across the four conditions were examined. Infants in the full-demonstration and failed-attempt conditions produced target acts more quickly than did infants in the adult-manipulation condition. Infants in the emulation-learning condition had an intermediate latency to produce target acts. The data on whether infants touched the object sets at the parts consistent with the experimenter’s demonstration (note that in the emulation-learning condition, this was unobserved by the infants) may provide a clue as to what underlies this pattern. Infants in the emulation-learning condition tended to touch different parts of the objects than the experimenter touched more frequently than did infants who observed the failed-attempt demonstration. Remember that infants in the emulation-learning condition had not observed the experimenter manipulating the object sets;, they merely saw the initial and end states. It might be that they required more orientation and exploration of the object sets before the affordances were revealed and they were induced to perform the target act. The infants in the emulation-learning condition had an opportunity to learn that the objects could be linked or configured in a specified way (e.g., the beads go *in* the cup). However, they had less exposure to the objects in motion and may therefore have engaged in more exploratory behavior at the beginning of the test trial to familiarize themselves with more basic, elemental properties of the objects, for example, weight. Notwithstanding this, the immediacy of "imitation" may be more adequately captured by the order in which target acts are produced than by the latency at which they are produced.

One helpful framework to help us understand this pattern of findings is that of Carpenter and Call (Call & Carpenter, in press; Carpenter & Call, 2002). They highlighted three sources of information available to the observer in the behavioral reenactment paradigm: the actions observed, the results of the actions, and the (intended) goal of the demonstrator. Only in the full-demonstration condition were all three sources of information available to the infants. This fact may explain why they produced more target acts at first action than the infants in the three other conditions. In the emulation-learning condition, infants had only the results of the action available to them (unless one argues that the infants were inferring the goals of the experimenter who performed the manipulation unseen by them, for which there is no clear evidence). This may explain why they were more likely to initially touch different object parts (which is unsurprising because they had no cue as to where the objects should be manipulated in order to efficiently produce the target act) and perhaps also why they took (nonsignificantly) longer to produce target acts than did infants in the full-demonstration and failed-attempt conditions. Infants in the adult-manipulation condition touched the same parts of the object sets manipulated by the experimenter, but these did not always involve a strong cue to the afforded target acts. This may explain why these infants produced the least target acts and why when they did produce target acts they took longer to do so than infants in the other conditions. The Carpenter and Call framework provides a potential explanation for the pattern of findings that does not require that infants in the failed-attempt condition (or indeed in the full-demonstration condition) necessarily attribute intentions to the experimenter. The goal of the demonstrator is only one of the three sources of information the observer can use to guide his or her response.

Although the findings of the study are broadly in line with those of Meltzoff (1995) and Bellagamba and Tomasello (1999), there were some minor discrepancies. Although there was no significant difference between the full-demonstration, failed-attempt, and emulation-learning conditions in terms of proportion of target acts produced in the 20-s response period, the absolute level of target acts produced did not quite match the level found in the previous studies. Further, the proportion of target acts produced by infants in the emulation-learning condition was nonsignificantly higher than that produced by infants in the adult-manipulation condition in the 20-s response period. The proportion of target acts produced in 20 s in the full-demonstration condition (.76) was similar to those reported by Meltzoff (.76) and Bellagamba and Tomasello (.84). However, the proportion of target acts in the failed-attempt condition was lower (.54) than those in Meltzoff's (.80) and Bellagamba and Tomasello's (.72) studies. Note that the scoring of these actions was highly reliable. Although the failed-attempt procedure was based on Meltzoff's (1995) description, we cannot rule out that the procedure might in some way have been conducted differently and led to a reduced production of target acts. However, one systematic difference between the present study and those of Meltzoff (1995) and Bellagamba and Tomasello (1999) is that each action observed on the videotapes in the present study was scored into one of five mutually exclusive categories. Although the proportion of failed-attempt acts, adult-manipulation acts, and "other" acts was low across all four groups when first actions only were considered (see Table 2), in subsequent actions more of these acts were scored. We independently scored the first and second actions produced, but because the pattern of findings did not differ, for reasons of clarity in the present article we present data only for the first action and the number of target acts in the 20-s response period. When first and second actions are included, the infants in the failed-attempt condition produced failed-attempt acts in 6% of trials (which could be considered "near-miss" target acts). In the emulation-learning condition, infants produced failed-attempt acts in 6% of trials and target acts using their fingers (and not the stick) in the box and stick object set in 12% of trials. The approach we adopted of scoring each action into mutually exclusive categories might have resulted in behaviors close to target acts being scored into another category, deflating the overall level of target acts produced. Although this slight discrepancy between the findings of the current study and those of Meltzoff (1995) and Bellagamba and Tomasello (1999) introduces a note of caution, we do not believe that it undermines the overall pattern of findings, which was broadly consistent with that of previous studies. Note that the latencies to produce target acts in the full-demonstration and failed-attempt conditions were similar to those in Meltzoff's (1995) study.

Another contrast is that Bellagamba and Tomasello (1999) found that 18-month-old infants performed more target acts after observing the failed-attempt model than after observing the end states of the target demonstration. The results of the current study did not replicate this finding. One critical difference is that in the present study, infants were exposed to both the initial and the end states of the object sets in the emulation-learning condition, whereas in Bellagamba and Tomasello's (1999) study infants observed the end state only. Thus, more information about the object-afforded properties was available to the infants in the current study than to those in Bellagamba and Tomasello's study. This may explain why a stronger effect of emulation learning was observed.

One final interpretation is that infants selectively reproduced outcomes of demonstrated acts when they were of certain kinds. Reproduction of the non-target-relevant control acts observed in the adult-manipulation condition and of the failed acts observed in the failed-attempt condition was rare. The proportions, counting first and second actions, were 10% and 6%, respectively. Under Thorpe's (1963) definition, infants were not imitating the actions demonstrated to them in these conditions, in contrast to the situation in the full-demonstration condition. Why not? It might be that infants in the full-demonstration condition found the observed outcomes more salient and were more motivated to reproduce them. In contrast, the observed outcomes resulting from the non-object-afforded control acts in the adult-manipulation condition might have been less salient to the infants. In the same way, it might be that after observing the failed-attempt model, the infants produced the target acts in preference to the acts actually demonstrated because they found the afforded target acts more salient. That is, they might have learned the dynamic affordances of the objects during observation of the failed-attempt display, and that might have induced them to produce the target acts (Custance et al., 1999). That is, infants rarely imitated demonstrated actions when these did not specify or coincide with the affordances of the objects.

These findings challenge Meltzoff's (1995) and Bellagamba and Tomasello's (1999) intentional interpretation of the behavioral reenactment paradigm. If infants are capable of reproducing intended actions, should they not be equally capable of imitating the observed outcomes in the adult-manipulation and the failed-attempt conditions, because these were intended and consummated actions on the part of the demonstrator? Unless one could show that the experimenter's failure to consummate the target acts was accidental (see Meltzoff, 1996, cited in Meltzoff, Gopnik, & Repacholi, 1999, for an innovative attempt to do this), it would not be evident to an observer that the demonstrator in the failed-attempt condition had been unsuccessful in completing the intended act.

Experiment 2

The findings of Experiment 1 suggested that emulation learning may account for infants' overall performance of target acts in the 20-s response period in both the failed-attempt and the emulation-learning conditions. Might other aspects of nonimitative learning also influence infants' response in the behavioral reenactment paradigm? In the failed-attempt condition, not only does the experimenter manipulate the target-relevant parts of the object set but he or she also moves them spatially close to one another in order to transform the object set from its initial state to the unconsummated failed-attempt display. Thus, infants might be attracted to the spatial contiguity of the target-relevant parts of the object set during observation of the failed-attempt model. This could be considered a form of stimulus enhancement. Stimulus enhancement refers to situations in which an observer's attention is drawn to a part of an object by the actions of the demonstrator (Spence, 1937; Whiten & Ham, 1992). It is implicitly assumed in the animal literature that the demonstrator's contact with a stimulus is also likely to attract an observer's attention and to facilitate responding to the stimulus (Heyes, 1994; Zentall, 1996). Experiment 2 was designed to explore how being exposed to the initial and transitional states of the object set (but not the consummated or unconsummated end state, as in the full-demonstration and failed-attempt conditions) influences infants' performance in the behavioral reenactment paradigm.

The spatial contiguity of the target-relevant parts of the object sets (with the exception of the dumbbell) is a critical distinction between the displays observed by infants in the failed-attempt and the adult-manipulation conditions. For example, in the failed-attempt condition, the beads touched the upper rim of the cylinder each time before they "accidentally" fell to the table. In contrast, in the adult-manipulation display, the transitional state did not involve the spatial contiguity of the target-relevant parts of the objects, because the beads fell to the table without touching any part of the cylinder. Would infants be induced to produce the target acts after observing spatial contiguity of the target-relevant parts of the object sets?

In Experiment 2 we replicated the full-demonstration, failed-attempt, and emulation-learning conditions of Experiment 1, but we added a second novel condition: the spatial contiguity condition. Three distinguishing features characterized the settings of the spatial contiguity condition: First, as in the full-demonstration and failed-attempt conditions, the experimenter acted at the target-relevant parts of the objects. Second, the experimenter moved the parts of the objects close to one another and held the target-relevant parts in close spatial contiguity. Third, whereas the modeled action was repeated three times with each object set in the full-demonstration and failed-attempt conditions, each spatial contiguity setting was presented only once in the modeling phase. If the experimenter repeatedly displayed the same setting, the display might be indistinguishable from the failed-attempt display. Because each setting was presented once rather than three times, the spatial contiguity condition provided a conservative test of the hypothesis.

Method

Participants

Forty 17-month-old infants (mean age = 17.3 months, *SD* = 1.6) from London, England participated in the study. They were recruited from a number of playgroups and health centers with posters and invitations from their health visitors. There were 20 boys and 20 girls. No infant was dropped from the final sample. The sample was 67.5% White Caucasian, 20.0% Asian, and 12.5% African/Caribbean.

Test Situation

The testing took place in a consulting room at a health center ($n = 9$), at home if such an arrangement was favored by parents ($n = 25$), or at a laboratory in the Department of Psychology at University College London ($n = 6$). The test situation, including the placement of the video camera, the warm-up procedure, and the instructions for parents, was identical to that described in Experiment 1.

Test Materials

The test objects were the same as those used in Experiment 1 and were replicas of the five object sets used in Meltzoff's (1995) study.

Experimental Design

There were four conditions in the study: the full-demonstration, failed-attempt, emulation-learning, and spatial contiguity conditions.

Procedure

The demonstrations presented in the full-demonstration, failed-attempt, and emulation-learning conditions were identical to those described in Experiment 1. In the spatial contiguity condition, the experimenter moved the two individual parts of the object set to bring them in close proximity so that the target-relevant parts were spatially contiguous with each other. In a sense, the spatial contiguity display was used to mimic the transitional states prior to the consummation of the target acts in the full-demonstration condition and the "accidental" nonconsummation of target acts in the failed-attempt condition. Such states therefore occurred in the process of demonstrating both the target acts and the failed acts. Furthermore, because infants might interpret a series of movements in a single demonstration period as the adult repeatedly attempting (but failing) to produce the target act, each static object array in the spatial contiguity demonstration was presented only once for 10 s. The object set was brought back to its initial state. As in the other three conditions, the experimenter completed each whole spatial contiguity display in approximately 20 s; then the object set was handed to the infant.

The following paragraphs describe the modeling procedure in the *spatial contiguity* condition:

Dumbbell. In contrast to the other object sets, in which the target acts required infants to fashion the target configurations from the separate parts of the objects, the target act involved in the dumbbell object set required infants to take apart a configuration. Thus, rather than moving one half of the dumbbell adjacent to the other half, the experimenter merely picked it up by the two cubes and then held it still in a horizontal position for 10 s. After this, the dumbbell was put back on the table. During the modeling period, the cubes were never pulled outward or pushed inward, nor did the experimenter's hands leave the cubes.

Box and stick. The experimenter picked up the stick and then held it still in a vertical position above the button on the top of the box at a distance of approximately 1 cm for 10 s. After this, the stick was put back where it was picked up initially. During the modeling period, the stick was never pushed into the button, nor did it ever move across or touch the top of the box.

Prong and loop. The experimenter raised the loop and then held it still in front of the bulbous tip of the prong at a distance of approximately 1 cm for 10 s. After this, the loop was put back where it was picked up initially. During the modeling period, the loop was never moved closer to the tip, and thus the loop never went beyond the tip, nor did it ever rest on the prong.

Beads and cylinder. The experimenter raised the beads and then held the vertically suspended chain of beads still approximately 1 cm above the upper rim of the cylinder for 10 s. After this, the beads were put back where they were picked up initially. During the modeling period, the beads were never lowered into the cylinder, nor were they released so as to fall to the table outside the cylinder.

Square and dowel. The experimenter picked up the square with two hands and then held it still in a horizontal position above the wooden base at a distance of approximately 1 cm for 10 s. Thus, the dowel standing on the wooden base was directly below the round hole in the center of the square. After this, the square was put back where it was picked up initially. During the modeling period, the square was never moved closer than 1 cm to the wooden base. The dowel never protruded through the round hole, nor did the square ever lie across the base.

Scoring

The scoring followed the procedure used in Experiment 1. Target acts produced within the 20-s response period were counted, and the first actions produced by the infants were scored according to five categories: target act, failed act, spatial contiguity, other act, and no act. Except for the category of spatial contiguity, the scoring criteria were identical to those described in Experiment 1. The criteria for scoring the category of spatial contiguity are shown in Appendix B.

Interrater Reliability

Chi-Tai Huang coded the infants' responses to each of the five test objects from the videotapes. A colleague who was taught to use the scoring system coded 30% of the data (3 children per condition) independently for the purpose of assessing interrater reliability. As in Experiment 1, reliability was calculated for the infants' first acts coded as falling into one of the five mutually exclusive scoring categories and for target acts produced within the 20-s response period. Agreement was high: For target acts produced in the 20-s response period, $\kappa = .93$; for first acts across the five mutually exclusive scoring categories, $\kappa = .86$.

Results

As in Experiment 1, the number of acts falling into each of the scoring categories was transformed into a proportion because 3 participants did not have a complete record of five response periods. One infant in the full-demonstration group walked away when the object set of box and stick was placed in front of her, apparently because she was scared of the beeping noise made by the experimenter pressing the buzzer. Two other missed data points were caused by a camcorder fault during the experiment: 1 infant's response to the loop and prong in the emulation-learning group and 1 infant's response to the beads and cylinder in the full-demonstration group. Table 4 shows the number of children producing target acts in the 20-s response period and at first action as a function of group (compare to Table 1, Meltzoff, 1995, p. 842). Table 5 shows the proportion of children producing target acts, failed attempts, spatial contiguity acts, other acts, and no acts as a function of group (compare to Table 2, Meltzoff, 1995, p. 843 and to Table 1, Bellagamba & Tomasello, 1999, p. 280). The data for target acts produced within the 20-s response period and for first action were entered into one-way ANOVAs with experimental condition as the between-subjects factor.

The effect of condition on the proportion of target acts produced in the 20-s response period reached only a marginally significant level, $F(3, 36) = 2.64$, $p = .064$. Follow-up Tukey's HSD tests showed that the infants in the full-demonstration condition produced more target acts in the 20-s response period than did the infants in the emulation-learning condition. However, the statistical significance was marginal ($p = .059$). There were no other group differences. There was a significant difference in the proportion of target acts produced at the first action as a function of condition, $F(3, 36) = 8.20$, $p < .001$. Follow-up Tukey's HSD tests showed that infants in the full-demonstration condition produced significantly more target acts as their first acts than did infants in the failed-attempt, spatial contiguity, and emulation-learning conditions ($p < .01$, $p < .01$, and $p < .001$, respectively). No group differences were found among the latter three conditions.

Table 4
Number of Infants Producing Target Acts in the 20-s Response Period and at First Action as a Function of Group

	Number of target acts					
Group	0	1	2	3	4	5
20-s response period						
Full demonstration[a]	0	0	2	3	5	0
Failed attempt	2	1	3	2	1	1
Spatial closeness	1	2	2	3	1	1
Emulation learning[a]	1	2	5	1	1	0
First action						
Full demonstration[a]	1	0	1	5	3	0
Failed attempt	4	2	2	2	0	0
Spatial closeness	2	4	2	2	0	0
Emulation learning[a]	3	6	1	0	0	0

[a] Two trials missing for 1 subject in the full-demonstration group and one trial missing for 1 subject in the emulation-learning group.

Table 5
Proportion of Infants Producing Target Acts Within the 20-s Response Period as a Function of Group and the Proportion of Infants' Responses Falling Into Each of the Scoring Categories at First Action

Action	Full demonstration		Failed attempt		Spatial contiguity		Emulation learning	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
				20-s response period				
Target acts	.70	.19	.44	.32	.48	.30	.39	.22
				First action				
Target acts	.62	.27	.24	.25	.28	.22	.16	.13
Failed attempt	.04	.06	.06	.10	.04	.08	.04	.08
Spatial closeness	.04	.08	.04	.08	.08	.14	.05	.10
Other acts	.33	.21	.66	.27	.60	.31	.72	.17
No acts	.00	.00	.00	.00	.00	.00	.00	.00
Finger[a]	.00	.00	.00	.00	.00	.00	.04	.08
Total	1.00		1.00		1.00		1.00	

[a] Proportion of infants activating the buzzer in the box and stick object set with their fingers.

As can be seen in Table 5, the infants in the failed-attempt condition reproduced few of the demonstrated failed attempts they had observed (6% at first action). Similarly, infants in the spatial contiguity condition reproduced relatively few of the acts demonstrated (8% at first action). There was a significant difference in the proportion of "other" acts produced at the first action as a function of condition, $F(3, 36) = 4.95$, $p < .002$. Pairwise comparisons with a post hoc Tukey's HSD test indicated that infants in the full-demonstration condition produced fewer "other" acts at first action than did the infants in the failed-attempt ($p < .001$) and emulation-learning conditions ($p < .01$). The comparison with the spatial contiguity condition approached significance ($p = .077$). The failed-attempt, emulation-learning, and spatial contiguity groups did not differ from one another.

Table 6 shows the proportion of object parts infants first touched and, in particular, whether those parts were consistent or inconsistent with those first touched by the experimenter. A one-way ANOVA performed on the proportion of first-touched object parts that were consistent with those the experimenter had first touched revealed a significant effect of condition, $F(3, 36) = 4.75$, $p < .01$. Follow-up Tukey's HSD tests showed that infants in the full-demonstration condition more often first touched the same object parts as the experimenter than did infants in the emulation-learning condition ($p < .005$). In terms of the proportion of first-touched object parts that were different from those the experimenter had first touched, there was a significant difference as a function of condition, $F(3, 36) = 4.05$, $p < .05$. Follow-up Tukey's HSD tests showed that infants in the emulation-learning condition more frequently first touched different parts of the object sets from the experimenter than did infants in the full-demonstration condition ($p < .01$).

The mean latencies to produce the target acts in the 20-s response period (and *SD*s) were as follows: full demonstration, 6.12 s (3.58); failed attempt, 8.40 s (2.69); spatial contiguity, 8.41 s (3.71); and emulation learning, 7.52 s (4.40). No significant effect of condition was found, $F(3, 32) = 0.81$, $p = ns$.

Discussion

The findings of the present study suggest that both emulation learning and stimulus enhancement may account for infants' performance of target acts after observing failed attempts in Meltzoff's behavioral reenactment paradigm. Both in terms of target acts produced within the 20-s response period and at first action,

Table 6
Proportion of Parts of Objects Infants First Touched in the Response Period

Condition	Part touched consistent with the demonstration		Part touched different from the demonstration		Touched more than one part		No response	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Full demonstration	.92	.15	.02	.06	.07	.14	.00	.00
Failed attempt	.70	.17	.22	.20	.08	.14	.00	.00
Spatial closeness	.80	.25	.18	.26	.02	.06	.00	.00
Emulation learning	.57	.25	.34	.25	.09	.11	.00	.00

the failed-attempt, emulation-learning, and spatial contiguity groups did not differ from one another. When target acts produced in the 20-s response period were considered, the full-demonstration group showed a nonsignificant trend to produce more target acts than the emulation-learning group but did not differ from the failed-attempt or spatial contiguity groups. However, at first action, the full-demonstration group produced more target actions than all three other groups. After observing the full demonstration of the target acts, infants imitatively reproduced such acts as their first acts, in contrast to the first actions produced following observation of the other types of demonstration. However, both in terms of target acts produced in the 20-s response period and at first action, the infants in the failed-attempt condition did not produce more target acts than the infants in the spatial contiguity and emulation-learning conditions.

The spatial contiguity model was intended to focus children's interest on specific settings in which the target-relevant parts of the objects were contiguous to one another with a minimum of action content. However, the spatial contiguity demonstration might have shed light on the dynamic affordances of the objects when the experimenter moved the object set from its initial state to its transitional state of spatial contiguity. The sequences of movement required for transforming the object set from its initial state to its transitional state could probably have elicited an effect similar to emulation learning. That is, children might have learned about the afforded end states of the target acts by observing the track of object movement. Unless the modeling procedure could prevent infants from seeing the experimenter transform the object set (e.g., by the use of a screen, as in Experiment 1), the spatial contiguity display would unavoidably involve target-relevant acts. Future studies should aim to disentangle the relative differential effects of nonimitative learning processes within the behavioral reenactment paradigm.

In common with the results of Experiment 1, the overall level of target acts produced in the failed-attempt condition is somewhat lower than the level in previous studies. The categorization of each response into one of five mutually exclusive categories may explain this difference. For example, in the failed-attempt condition, 10% of responses were scored as failed attempts and a further 6% of responses were scored as spatial contiguity responses at first and second actions combined (unreported data). Both of these responses can be considered "near-miss" target acts, perhaps reducing the number of responses categorized as full target acts. Similar proportions were also categorized as such in the spatial contiguity (6% and 14%, respectively) and emulation-learning (8% and 5%, respectively) conditions. Once again, the response scoring was highly reliable. The replication of the data across both Experiments 1 and 2 also adds to our confidence in the findings.

General Discussion

It appears that the nonimitative learning processes of emulation learning (reacting to observation of the initial and end states but seeing no modeled transformation of the objects sets) and stimulus enhancement (reacting to spatial contiguity of the target-relevant parts) were sufficient to induce infants to produce the target actions as frequently as in Meltzoff's intention, or failed-attempt, display. These findings present a challenge to Meltzoff's (1995) and Bellagamba and Tomasello's (1999) interpretation that infants in the failed-attempt condition produced the target acts by reenacting the demonstrator's intended but unconsummated actions.

Across both studies, three findings suggest an alternative to the intention attribution account. First, and most striking, were the findings from the first action scoring. The full-demonstration display induced infants to produce the target act. This was not so for the three other demonstrated actions. In terms of Carpenter and Call's analysis (Call & Carpenter, in press; Carpenter & Call, 2002), in the full-demonstration display, infants had three potential sources of information: the actions observed, the results of the actions, and the (intended) goal of the demonstrator. In this condition only were these three sources sufficient for infants to reproduce (imitate) the observed (target) action at first action. The findings do not allow us to parse the contributions of each of these three sources of information in influencing infants' responses. However, the sources of information in the three other conditions were not sufficient to influence the infants to produce the target act at first action. Infants in the failed-attempt, spatial contiguity, and emulation-learning conditions tended to produce other (exploratory?) actions at first action, in contrast to infants who had witnessed the full-demonstration display. However, once the infants had begun to act on the objects, they did produce more target acts as subsequent actions, perhaps as a result of learning more about the natural affordances of the object sets. There were no differences in latency to produce target acts between the groups, suggesting once again that first action may be a more revealing index of immediacy of imitation than latency.

The second suggestive piece of information is that infants in the emulation-learning condition first touched different parts of the objects sets than the experimenter touched (recall that they had not witnessed the manipulation as it occurred behind a screen) more frequently than did infants in the other three conditions and significantly more so than did infants who observed the full-demonstration display. Thus, it appears that orientation to the target-act-relevant parts of the object sets (in the failed-attempt and spatial contiguity conditions), exposure to the afforded target acts of the object sets (in the emulation-learning conditions), and some experience in manipulating the object sets are required for infants to be induced to produce the target acts in the absence of observation of the full-demonstration display.

In addition, object affordances also play a role in determining infants' response in the behavioral reenactment paradigm. The strongest evidence for this role is the reluctance of infants to reproduce modeled actions that are not consistent with the object affordances of the object sets. Infants in the failed-attempt, spatial contiguity, and adult-manipulation conditions did not fail to reproduce the observed acts because these acts entailed no intention content. Indeed, for the experimenter, these actions required, if anything, more concentration and deliberate manipulation of the object sets than did the full-demonstration manipulation. Infants' imitative performance in situations involving actions on objects is highly reliant on the types of demonstrated acts and occurs, for example, when the observed outcomes of the acts specify both goals and affordances (Call & Carpenter, in press; Heyes & Ray, 2002). Thus, a critical methodological issue in using the behavioral reenactment paradigm to investigate infants' understanding of intentions is the need to separate the object affordances from consummated and unconsummated intended outcomes and, further, to separate body movements from object movements.

The overall pattern of findings is consistent with accounts that propose a role for nonimitative social learning influences in reproducing actions on objects. These include emulation learning (Tomasello, 1990, 1996; Whiten & Custance, 1996; Whiten & Ham, 1992), stimulus enhancement (Heyes, 1994; Spence, 1937; Whiten & Ham, 1992; Zentall, 1996), and object movement reenactment (Custance et al., 1999). These may provide a more parsimonious explanation of the performance of target acts following the failed-attempt display than the intention attribution account put forward by Meltzoff (1995) and Bellagamba and Tomasello (1999). As argued earlier, in terms of the level of both inferential (Heyes & Ray, 2002) and representational (Barresi & Moore, 1996) complexity, this nonimitative social learning account has the appeal of parsimony. The present study does not allow us to parse the influences of each of these learning processes, and this should be the goal of future studies. The finding that few failed-attempt and spatial contiguity acts were produced also indicates that strongly afforded actions may be more likely to be reproduced than other less afforded manipulations of the object sets. One goal of future studies should be to see what social or nonsocial cues are required to induce infants to reproduce such displays. Under Carpenter and Call's (2002) analysis, the strength of particular object-afforded actions may need to be incorporated into their model of the three information sources that influence imitation.

We cannot rule out that in everyday situations, reading adults' intentions is irrelevant to imitation of actions by infants in the 2nd year of life. Rather, we have adopted a parsimonious approach specifically to the interpretation of infants' responses in the behavioral reenactment paradigm in order to rule out the effects of nonimitative learning processes. A parsimonious interpretation may be particularly important when using the behavioral reenactment paradigm to investigate the cognitive ability of atypically developing children. For example, although there is evidence that infants with autism do not reproduce even simple actions on objects (Charman et al., 1997, 1998), by school age, autistic children do reproduce simple modeled actions on objects (Charman & Baron-Cohen, 1994). Under the above analysis that both social and object learning processes may underlie responses in the behavioral reenactment paradigm, the finding that children with autism produced target acts following a failed-attempt display (Aldridge et al., 2000) may not pose a challenge to established theories of the development of imitative ability in autism (Charman & Huang, 2002; Rogers & Pennington, 1991).

We do not wish to make the case that in everyday situations, reading adults' intentions is irrelevant to imitation of actions by infants. Rather, it is notable that in everyday situations, social, vocal and affective cues are part and parcel of imitative exchanges. To date, there has been little developmental research attempting to assess the effect of nonimitative social learning, in contrast to the situation in the animal literature (see Want & Harris, 2001, for a notable exception). As Want and Harris (2002) pointed out, the challenge for developmental psychologists is to parse the roles of these different processes in experimental studies. Some work on the role of intentional cues has begun (Carpenter, Akhtar, & Tomasello, 1998). We have adopted a different methodological approach that may help in this enterprise.

References

Abravanel, E., & Gingold, H. (1985). Learning via observation during the second year of life. *Developmental Psychology, 21*, 614–623.

Aldridge, M. A., Stone, K. R., Sweeney, M. H., & Bower, T. G. R. (2000). Preverbal children with autism understand the intentions of others. *Developmental Science, 3*, 294–301.

Bakerman, R., & Adamson, L. (1984). Co-ordinating attention to people and objects in mother–infant and peer–infant interactions. *Infant Development, 55*, 1278–1289.

Baron-Cohen, S. (1991). Precursors to a theory of mind: Understanding attention in others. In A. Whiten (Ed.), *Natural theories of mind: Evolution, development and simulation of everyday mindreading* (pp. 233–251). Oxford, England: Blackwell.

Barresi, J., & Moore, C. (1996). Intentional relations and social understanding. *Behavioral and Brain Science, 19*, 107–154.

Bellagamba, F., & Tomasello, M. (1999). Reenacting intended acts: Comparing 12- and 18-month-olds. *Infant Behavior and Development, 22*, 277–282.

Bretherton, I. (1991). Intentional communication and the development of an understanding of mind. In D. Fry & C. Moore (Eds.), *Children's theories of mind: Mental states and social understanding* (pp. 49–75). Hove, England: Erlbaum.

Call, J., & Carpenter, M. (in press). Three sources of information in social learning. In K. Dautenham & C. Nehaniv (Eds.), *Imitation in animals and artifacts*. Cambridge, MA: MIT Press.

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

Carpenter, M., & Call, J. (2002). The chemistry of social learning. *Developmental Science, 5*, 22–24.

Carpenter, M., Nagell, K., & Tomasello, M. (1998). Social cognition, joint attention and communicative competence from 9 to 15 months of age. *Monographs of the Society for Research in Child Development, 63*, 1–143.

Charman, T. (2000). Theory of mind and the early diagnosis of autism. In S. Baron-Cohen, H. Tager-Flusberg, & D. Cohen (Eds.), *Understanding other minds: Perspectives from developmental cognitive neuroscience* (pp. 422–441). Oxford, England: Oxford University Press.

Charman, T., & Baron-Cohen, S. (1994). Another look at imitation in autism. *Development and Psychopathology, 6*, 403–413.

Charman, T., Baron-Cohen, S., Swettenham, J., Baird, G., Cox, A., & Drew, A. (2000). Testing joint attention, imitation and play as infancy precursors to language and theory of mind. *Cognitive Development, 15*, 481–498.

Charman, T., Baron-Cohen, S., Swettenham, J., Cox, A., Baird, G., & Drew, A. (1998). An experimental investigation of social-cognitive abilities in infants with autism: Clinical implications. *Infant Mental Health Journal, 19*, 260–275.

Charman, T., & Huang, C. T. (2002). Delineating the role of stimulus enhancement and emulation-learning in the behavioral reenactment paradigm. *Developmental Science, 5*, 25–27.

Charman, T., Swettenham, J., Baron-Cohen, S., Cox, A., Baird, G., & Drew, A. (1997). Infants with autism: An investigation of empathy, pretend play, joint attention and imitation. *Developmental Psychology, 33*, 781–789.

Custance, D., Whiten, A., & Fredman, T. (1999). Social learning of an artificial fruit task in capuchin monkeys (*Cebus apella*). *Journal of Comparative Psychology, 113*, 13–23.

Devouche, E. (1998). Imitation across changes in object affordances and social context in 9-month-old infants. *Developmental Science, 1*, 65–70.

Galef, B. G. (1988). Imitation in animals: History, definition and interpretation of data from the psychological laboratory. In T. R. Zentall & B. G. Galef (Eds.), *Social learning: Psychological and biological perspectives* (pp. 3–28). Hillsdale, NJ: Erlbaum.

Heyes, C. M. (1994). Social learning in animals: Categories and mechanisms. *Biological Reviews, 69*, 207–231.

Heyes, C. M. (1996). Genuine imitation? In C. M. Heyes & B. G. Galef (Eds.), *Social learning in animals: The roots of culture* (pp. 371–389). London: Academic Press.

Heyes, C. M. (2001). Causes and consequences of imitation. *Trends in Cognitive Science, 5,* 253–261.

Heyes, C. M., & Ray, E. D. (2002). Distinguishing intention-sensitive from outcome-sensitive imitation. *Developmental Science, 5*, 34–36.

Jones, S. (1996). Imitation or exploration? Young infants' matching of adults' oral gestures. *Infant Development, 67*, 1952–1969.

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

Meltzoff, A. N. (1988b). Infant imitation and memory: Nine-month-olds in immediate and deferred tests. *Infant Development, 59*, 217–225.

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

Meltzoff, A. N. (1996, August). *Understanding intentions in infancy*. Paper presented at the 26th International Congress of Psychology, Montreal, Quebec, Canada.

Meltzoff, A N., & Gopnik, A. (1993). The role of imitation in understanding persons and developing a theory of mind. In S. Baron-Cohen, H. Tager-Flusberg, & D. Cohen (Eds.), *Understanding other minds: Perspectives from autism* (pp. 335–366). Oxford, England: Oxford University Press.

Meltzoff, A. N., Gopnik, A., & Repacholi, B. M. (1999). Toddlers' understanding of intentions, desires and emotions: Explorations of the dark ages. In P. D. Zelazo, J. W. Astington, & D. R. Olson (Eds.), *Developing theories of intention* (pp. 17–41). Mahwah, NJ: Erlbaum.

Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science, 198*, 75–78.

Meltzoff, A. N., & Moore, M. K. (1983a). Newborn infants imitate adult facial gestures. *Infant Development, 54*, 702–709.

Meltzoff, A. N., & Moore, M. K. (1983b). The origins of imitation in infancy: Paradigm, phenomena, and theories. In L. P. Lipsitt (Ed.), *Advances in infancy research* (Vol. 2, pp. 265–301). Norwood, NJ: Ablex.

Moerk, E. L. (1989). The fuzzy set called "imitation. " In G. E. Speidel & K. E. Nelson (Eds.), *The many faces of imitation in language learning* (pp. 277–303). New York: Springer-Verlag.

Piaget, J. (1962). *Play, dreams and imitation in infanthood*. (C. Gattegno & F. M. Hodgson, Trans.). London: Routledge & Kegan Paul. (Original work published 1951)

Rogers, S. J., & Pennington, B. F. (1991). A theoretical approach to the deficits in infantile autism. *Development and Psychopathology, 3*, 137–162.

Snow, C. E. (1981). The use of imitation. *Journal of Child Language, 8*, 205–212.

Spence, K. (1937). Experimental studies of learning and higher mental processes in infrahuman primates. *Psychological Bulletin, 34*, 806–850.

Thorpe, W. (1963). *Learning and instinct in animals*. London: Methuen.

Tomasello, M. (1990). Cultural transmission in the tool use and communicatory signaling of chimpanzees? In S. T. Parker & K. R. Gibson. (Eds.), *'Language' and intelligence in monkeys and apes: Comparative developmental perspectives* (pp. 274–311). Cambridge, England: Cambridge University Press.

Tomasello, M. (1995). Joint attention as social cognition. In C. Moore & P. Dunham. (Eds.), *Joint attention: Its origins and role in development* (pp. 85–101). Hillsdale, NJ: Erlbaum.

Tomasello, M. (1996). Do apes ape? In C. M. Heyes & B. G. Galef (Eds.), *Social learning in animals: The roots of culture* (pp. 319–346). London: Academic Press.

Tomasello, M. (1999). Having intentions, understanding intentions and communicative intentions. In P. D. Zelazo, J. W. Astington, & D. R. Olson (Eds.), *Developing theories of intention* (pp. 63–75). London: Erlbaum.

Tomasello, M., Savage-Rumbaugh, E. S., & Kruger, A. (1993). Imitative learning of actions on objects by children, chimpanzees, and enculturated chimpanzees. *Child Development, 64*, 1688–1705.

Trevarthen, C., & Hubley, P. (1978). Secondary intersubjectivity: Confidence, confiding and acts of meaning in the first year. In A. Lock (Ed.), *Action, gesture and symbol: The emergence of language* (pp. 183–229). London: Academic Press.

Trevarthen, C., Kokkinaki, T., & Fiamenghi, G. A. (1999). What infants' imitations communicate: With mothers, with fathers and with peers. In J. Nadel & G. Butterworth (Eds.), *Imitation in infancy* (pp. 127–185). Cambridge, England: Cambridge 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. (2002). Primatology and developmental science: Who's aping whom? *Developmental Science, 5*, 36–38.

Whiten, A., & Custance, D. M. (1996). Studies of imitation in chimpanzees and children. In C. M. Heyes & B. G. Galef (Eds.), *Social learning in animals: The roots of culture* (pp. 291–346). London: Academic Press.

Whiten, A., Custance, D. M., Gomez, J. C., 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., & Ham, R. (1992). On the nature of imitation in the animal kingdom: Reappraisal of a century of research. *Advances in the Study of Behavior, 21*, 239–283.

Wood, D. (1989). Social interaction as tutoring. In M. H. Bornstein & J. S. Bruner (Eds.), *Interaction in human development* (pp. 59–80). Hove, England: Erlbaum.

Zentall, T. R. (1996). An analysis of imitative learning in animals. In C. M. Heyes & B. G. Galef (Eds.), *Social learning in animals: The roots of culture* (pp. 221–243). London: Academic Press.

(*Appendixes follow*)

Appendix A

Scoring Criteria

The operational definitions of each of these scoring categories were as follows:

Target Act

Dumbbell. The infant held the dumbbell by the two cubes and then pulled them outward so that the dumbbell split into two halves. If the dumbbell came apart at the first action and was followed by the infant putting the two halves back together to start another action, putting the two halves back together was regarded as a transition and was not coded as the second action. However, the "other act" code was assigned to the second action if the infant discontinued the response after the transition.

Box and stick. The infant held the stick upright and used it to push the recessed button on the top of the box so that the beeper inside the box was activated. If the beeper was activated by the stick at the first action and was followed by the infant pulling back the stick to start another action, pulling back the stick was regarded as a transition and was not coded as the second action. However, the "other act" code was assigned to the second action if the infant discontinued responding after the transition.

Loop and prong. The infant raised the loop up to the prong and then put it over the end so that the prong protruded through it. The loop did not have to rest on the very end of the prong, but it had to pass through the prong and go beyond its halfway point. If the loop came to rest on the prong at the first action and was followed by the infant removing the loop to start another action, removing the loop from the prong was regarded as a transition and was not coded as the second action. However, the "other act" code was assigned to the second action if the infant discontinued his or her response after the transition.

Beads and cylinder. The infant raised the chain of beads up over the upper edge of the cylinder and then put the beads into the cylinder so that the beads were deposited on its base. The beads did not need to be released from the infant's hand, but they had to be completely within the cylinder and underneath its opening edge. If the beads were put into the cylinder at the first action and were followed by the infant pulling the chain out of the cylinder to start another action, pulling the chain out of the cylinder was regarded as a transition and was not coded as the second action. However, the "other act" code was assigned to the second action if the infant discontinued responding after the transition.

Square and dowel. The infant 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 position of the square could be either upward or downward. If the square and the dowel were aligned at the first action and were followed by the infant separating one from the other to start another action, separating the square from the dowel was regarded as a transition and was not coded as the second action. However, the "other act" code was assigned to the second action if the infant discontinued the response after the transition.

Failed Act

Dumbbell. The infant picked up the dumbbell with both hands, and then one hand moved away from the cube without moving the two joined tubes so that the inner tube was never revealed. The direction of the hand movement could be left or right.

Box and stick. The infant held the stick upright and then put it down on the periphery of the recession on the top of the box. The stick overlapped the half of the recession that the button lay in. The tip of the stick did not go into the recession.

Loop and prong. The infant raised the loop up to the prong and then released it next to the bulbous tip so that the loop dropped to the table. The loop did not reach beyond the bulbous tip.

Beads and cylinder. The infant raised the chain of beads up over the upper edge of the cylinder and then released the beads next to the opening so that they fell to the table outside the cylinder. Some of the beads might remain inside the cylinder, but the rest of them that were revealed outside had to touch the table.

Square and dowel. The infant picked up the square and then put it over the dowel with a tilt so that the dowel did not protrude through the round hole in the center of the square; or the square slid off the dowel when it was placed over it. Some of the dowel might have crossed the edge of the hole, but the dowel never passed through it.

Adult Manipulation

Dumbbell. The infant held the dumbbell by the two cubes and then pushed them inward so that the two joint tubes were never moved outward.

Box and stick. The infant picked up the stick and then moved it horizontally against the top surface of the box. The movement could begin at any location on the top. The stick did not have to go over the whole surface, but it was never released when it was moving on the slope so that it slid down to the table.

Loop and prong. Because the manipulations demonstrated in this object set involved more than two steps (in contrast to the other objects), the action was coded as reproducing the adult's manipulation as long as it met any of the following definitions: (a) The infant picked up the loop and then moved it along the upper edge or base of the screen board. The loop never rested over the edge or the base when the movement ceased. (b) The infant picked up the loop and then dropped it at either end of the upper edge, or beneath the prong, so that the loop fell to the table. (c) The infant picked up the loop and then moved it along the upper edge or the base of the screen. The loop was released when it arrived at either end of the edge or passed beneath the prong.

Beads and cylinder. The infant picked up the beads and then dropped the vertically suspended chain all the way to the table beside the cylinder. The beads never touched any part of the cylinder.

Square and dowel. The infant held the square upright on its edge and then moved it along the edge of the wooden base plate. The location could be either side of the base.

Other Act

This code was assigned to those actions that did not fall within one of the above categories. It covered a wide range of actions, relevant or irrelevant to "target act," "failed act," or "adult manipulation." Some frequent examples were as follows: For the dumbbell, the infant held it by the tubular part, or twisted the cubes, or banged it on the table. For the box and stick, the infant turned the box upside down, or slid the stick down the top surface, or used the stick to probe the battery device inside, or merely held the stick in his or her hand. For the loop and prong, the infant grabbed the bulbous tip of the prong, or flicked the loop, or draped the loop on the upper edge of the screen board. For the beads and cylinder, the infant attempted to put the beads around the neck, or flicked the beads, or brought his or her mouth to the opening of the cylinder, or merely held the cylinder. For the square and dowel, the infant held the wooden plate by the dowel, or put the wooden plate over the square, or attempted to align both of them but in an upside-down position.

No Act

This code indicated that the infant did not respond and performed no action on the objects. It was assigned if the response met one of the following conditions: (a) The infant did not touch the object presented to him or her, or (b) the infant returned the object to the experimenter after he or she had already completed one action.

Appendix B

Scoring Criteria for Spatial Contiguity

Dumbbell

The infant held the dumbbell with two hands so that each hand grasped a cube. The cubes were never pulled outward or pushed inward. In cases where the infant held the dumbbell with two hands but one hand moved away from the cube, the action was scored as a failed act. If the infant twisted or moved the connecting tubular piece but without splitting the dumbbell into two halves, these actions were coded as an "other act." The "target act" code was assigned only when the dumbbell split into two.

Box and Stick

The infant raised the stick and then held it in an upright position at a distance from the button on the top of the box. The end of the stick never touched the top of the box. In cases where the stick was not above the half of the top in which the button was located, the act was scored as an "other" act. If the stick touched the box once, the action was scored as a failed act only when the stick touched the half of the top in which the button was located and did not go in the recession.

Loop and Prong

The infant picked up the loop and then held it in front of the bulbous tip of the prong. The infant never put the loop over the prong or dropped the loop to the table. The loop could cross some of the bulbous tip but never crossed it more than once and never went beyond it. If the loop crossed the tip once and did not go beyond it, the spatial contiguity code was assigned only if the loop was never released from the infant's hand; otherwise, the act was coded as a failed act. If the loop was held next to other parts of the prong rather than the bulbous tip, the act was scored as an "other" act.

Beads and Cylinder

The infant raised the beads and then held the chain of beads near the upper rim of the cylinder. Some of the beads were allowed to cross the rim only once, and the whole chain was never fully underneath the rim. If the beads crossed the edge once and did not completely go inside the cylinder, the spatial contiguity code was assigned to the act as long as the beads were not released from the infant's hand.

Square and Dowel

The infant picked up the square with either two hands or one hand and then held it in a horizontal position at a distance above the wooden base plate. The protruding post never crossed the round hole or the square, and the square never crossed the wooden base. If the square crossed the dowel once and the dowel did not pass through the round hole, the act was considered a failed act only when the square was released from the infant's hand and then remained over the dowel with a tilt or slid down it; otherwise, it was coded as an "other" act instead.

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