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Infants and Preschoolers Imitation of Object Manipulation: The Influences of Movement Path, Perceptual Saliency, and Task Constraints

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The goal-directed imitation theory suggests that imitation involves representing an observed action as a set of components that are hierarchically specified from major to less important goals. Given limited resources, children tend to encode end points as dominant over movement paths. Under this logic, two experiments were conducted here to examine imitative performance of infants and preschoolers using object manipulation tasks. In Experiment 1, the experimenter performed a sequence of two actions on objects unimanually with ipsilateral or contralateral hand paths. In each condition, some actions were followed by their salient effects; some were not. In Experiment 2, the adult manipulated two objects with the same hand while the other hand grasped a cup or was free staying close to chest. In two experiments, children from both age groups were likely to reenact the observed actions with ipsilateral hands. This ipsilateral preference was not affected by either perceptual saliency or task constraints. In contrast to the Bekkering, Wohlschl ger, and Gattis (2000) study, contralateral responses were relatively rare in the present study. While it may not be possible here to identify how much the goal-directed process reduces the tendency to copy the adult s behavioral strategy and contralateral actions, it is important to consider the constraints inherent in the current task.

Keywords: ***imitation, goal-directed imitation, understanding of intentions, tool use, action representation***

Imitation is a focus of contemporary research in many disciplines, including cognitive, comparative and developmental psychology; cognitive neuroscience; and robotics (Dautenhahn & Nehaniv, 2002; Hurley & Chater, 2005; Meltzoff

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& Prinz, 2002; Stamenov & Gallese, 2002). Imitation plays an important role in the development of cognitive and social skills. Infants efficiently learn about others actions through imitation without trial and error. Imitation is thus a complex behavioral phenomenon involving social interaction and perception-action coordination. A growing consensus has emerged among developmental psychologists about the intentional nature of imitative behavior. The intentionality-based view maintains that infants imitation of observed behavior is guided by attribution of a goal or intention to the model. Therefore, imitation can be used as a nonverbal test for the attribution of intention, one of the early precursors of theory of mind (Meltzoff, 2002; Tomasello & Carpenter, 2005).

The intentionality-based imitation theory rests on empirical studies showing that infants are capable of using a variety of cues to infer others intentions. These include failed attempts (Meltzoff, 1995), vocal cues (Carpenter, Akhter, & Tomasello, 1998), and task constraints (Gergely, Bekkering, & Kir ly, 2002). For example, in Meltzoff s innovative behavioral reenactment procedure, infants saw an adult model try but fail to produce certain target actions on test objects (e.g. pulling apart a dumbbell toy into two parts). Meltzoff found that 18-month-old infants were able to reenact target actions they had never witnessed, instead of a literal copy of failed attempts. Meltzoff interpreted the effects of observing failed attempts as infants reading the model s intended acts. This result has now been well replicated (Bellagamba & Tomasello, 1999; Huang, Heyes, & Charman, 2002; Johnson, Booth, & O Hearn, 2001; Sanefuji, Hashiya, Itakura, & Ohgami, 2004).

However, a range of nonimitative social learning processes recently discussed in the comparative literature provides a significant challenge for the role of intention reading in imitation (Heyes, 1998, 2001; Heyes & Ray, 2002; Tomasello, 1990, 1996; Want & Harris, 2002; Whiten & Ham, 1992; Whiten, Horner, Litchfield, & Marshall-Pescini, 2004). Some explanations include 1) stimulus enhancement: a model s action draws an observer s attention to specific parts of objects, resulting in more vigorous exploration of these parts; 2) emulation learning: an observer learns about stimulus consequences of the demonstration (i.e. affordances between objects) but not the model s behavioral strategy; and 3) mimicking: an observer reproduces the body movements of the model without an understanding of the goals of the model. In a series of studies, Huang and colleagues examined whether children s responses in Meltzoff s behavioral reenactment procedure could be due to nonimitative social learning (Huang & Charman, 2005; Huang, Heyes, & Charman, 2002, 2006). They found that emulation in the form of affordance learning or object movement reenactment may provide parsimonious alternatives to the behavioral reenactment data reported by previous researchers.

The goal-directed imitation theory advocated by Bekkering and colleagues is another prominent theory that was originally formulated to explain errors in children s arm movement imitation (Bekkering, Wohlschl ger, & Gattis, 2000; Gleissner, Meltzoff, & Bekkering, 2000; Gattis, Bekkering, & Wohlschl ger, 2002). It suggests that imitation involves a decomposition of an observed action into a set of components that are represented hierarchically. These components specify imitative goals from major to less important goals with respect to their functionality. When resources are limited, the goal-directed theory predicts that multiple goals compete for capacity, and that the major goals are imitated at the expense of the less important goals.

First, Bekkering, Wohlschl er, and Gattis (2000) modified the Head s (1920) hand-to-ear task. They presented 4- to 6-year-old children a series of unimanual and bimanual arm movements toward the ipsilateral or contralateral ear(s). Bekkering and colleagues found that imitation was less accurate during trials of contralateral unimanual movements. Under these circumstances children preferred to touch their ear mirroring the model s ear with the ipsilateral hand (i.e. contra-ipsi errors). This result has been interpreted as the mirroring ear being dominant over the movement path in the hierarchy. Contra-ipsi errors rarely occurred during trials of contralateral bimanual movements. It was suggested that the crossing of the arms was highly visually salient and became a dominant goal in the imitative response. In a second experiment, Bekkering and colleagues decreased the number of components implicated in the goal complexity by having the model touch only one ear unimanually. Under these conditions children were less likely to commit contra-ipsi errors. In the last experiment, the model touched one of two dots on a table unimanually (dot condition). As previously found, there were more contra-ipsi errors during trials of contralateral movements. When the model touched the same places on the table without dots (no-dot condition), children chose the correct hand path across both types of trials. Bekkering and colleagues suggested that the availability of dots occupied the top of the goal hierarchy, thereby interfering with selection of the correct hand.

Gleissner, Meltzoff, and Bekkering (2000) further delineated the roles of visual monitoring and spatial endpoint in imitation of manual gestures. They showed 3-year-old children a series of unimanual and bimanual arm movements toward ears or knees ipsilateral or contralateral to hands. Some trials involved the gestures ending up with hands touching ears or knees; some trials involved the gestures ending up with hands near these parts without contact. Gleissner et al. found that contra-ipsi errors occurred only when the gestures terminated in contact with endpoints regardless of whether they could be visually monitored. When unimanual gestures terminated near end points without contact, children made significantly fewer errors. These findings support the goal-directed notion that spatial endpoints and movement paths compete for limited processing resources during imitative reconstruction of observed acts.

In another series of experiments, Wohlschl ger, Gattis, and Bekkering (cited from Gattis, Bekkering, & Wohlschl ger, 2002) tested the goal-directed view by reducing goal competition in the hand-to-ear task. In one experiment, the hand-to-ear movement was presented in two steps: the experimenter first extended a hand, and the hand waited to move toward the ipsilateral or contralateral ear until the child extended a hand. As predicted, a decrease in competition resulted in the infrequent substitution of contralateral for ipsilateral hand movements. In the next experiment, the experimenter and the child put on one white glove and one black glove. Thus, the glove color highlighted the movement path of a particular hand during demonstration. Despite the salient cue of glove colors, the errors in hand selection on contralteral trials were just as frequent as those in the original hand-to-ear task. Lastly, Wohlschl ger et al. asked children to compare six photographs of an adult performing each of the six gestures involved in the hand-to-ear task with another six photographs of a boy performing the same gestures. Matching errors in photographs of contralateral gestures were not significantly more than those of ipsilateral gestures. Thus, children s errors in hand selection are due to imitation but not to perception of the difference between ipsilateral and contralateral actions.

More recently, Carpenter, Call, and Tomasello (2005) modified the dot task (Bekkering et al., 2000, Experiment 3) to make it more interesting to 12- and 18-month-old infants. An adult model moved a toy mouse to a toy house in front (House) or the same place on a table (No House). In some cases the adult slid the mouse and the action was accompanied by a long beeeeeeee sound; in other cases the adult hopped it and the action was accompanied by short bee-bee-bee-bee sound bites. Carpenter et al. found a higher tendency to copy these actions and sound effects in the No House condition. In contrast, in the House condition infants were likely to ignore the hopping action and its effects. These findings were consistent with the goal-directed view that infants interpreted the presence of the house as the adult s dominant goal, thereby choosing the house at the expense of actions and sound effects. By contrast, actions and sound effects took precedence in the goal hierarchy when there was no house present and infants were thus biased to copy the adult s action.

Conceptually, both the intentionality-based theory and the goal-directed theory contend that imitation is not merely a literal copy but involves an understanding of the intention or goal behind an observed behavior. Nonetheless, these theories rest on different assumptions concerning evidence of imitation. The goal-directed theory asserts that imitation is mediated by goal representation, capitalizing on the source of errors in imitation of bodily gestures (Wohlschl ger, Gattis, & Bekkering, 2003). On the contrary, the intentionality-based theory emphasizes that imitation is more efficient and accurate when there is availability of information about the intention state of the model performing manipulations (Carpenter, Call, & Tomasello, 2002; Tomasello & Carpenter, 2005).

Methodologically, support for the intentionality-based theory of imitation comes from empirical studies that based manipulation of intentional cues on object-related tasks. However, observation of object manipulation is likely to introduce children to the affordances of objects. In most cases the end result of an object-related action provides information about the affordance which characterizes the object s end-state configuration. Therefore, the end result specifies both the goal and the key affordance. Under these circumstances it may not be possible to discriminate between intention reading and emulation learning. Indeed procedures that discriminate between imitation and emulation have been rare within developmental research. Therefore, the question remains whether intention reading is a necessary component of imitation of object-related actions (for discussion, see Charman & Huang, 2002; Huang & Charman, 2005).

Instead of using object-related tasks, gestural imitation tasks have been exploited to establish evidence for the goal-directed view. In gestural imitation the absence of objects precludes learning by affordance detection. However, possibilities of emulation learning cannot be entirely ruled out. For example, Mataric and Pomplun (1998) showed that regardless of whether people are watching arm, hand or finger movements, passively or for subsequent imitation, they tend to fixate on the endpoint of the movement trajectory. This provides a possible explanation for the Bekkering et al. (2000) findings. It may be that children substitute arm movement paths but not ears because an ear is always at the endpoint of the arm movement that captures most of children s attention resources (Heyes, 2001). Hence, the substitution of contralateral for ipsilateral movements may be alternatively interpreted as end-state emulation one subtype of emulation learning (Whiten et al., 2004) where the ear is not necessarily encoded in terms of the highest goal. This makes a direct challenge to the goal-directed view: why the highest goal in imitation of a hand-to-ear movement is the endpoint but not the model s body movement?

On the other hand, to assess errors in hand and endpoint selection, the experimental procedure used in these studies requires children to imitate ipsilateral or contralateral modeled actions across blocks of trials. Thus, the participants in these studies were mainly preschoolers, perhaps because they were cooperative and could engage in repeated trials. Carpenter et al. s (2005) study tested young infants using a block design, but almost half of this sample (44%) dropped out due to low motivation and uncooperativeness. Nonetheless, by 18 months of age, infants have acquired the richness of social skills, ranging from language to joint attention skills (e.g. Carpenter, Nagell, & Tomasello, 1998). Infants younger than 12 months of age have already demonstrated the capability to copy a range of novel acts on objects by observation (Devouche, 1998; Killen & Uzgiris, 1981; Meltzoff, 1988a, 1988b). The underpinnings of infants social and cognitive competence constitute a gap that needs to be bridged in the goal-directed theory of imitation.

Furthermore, in the preceding studies by Bekkering and colleagues, the highest goal of an imitative act specifies either a static endpoint or a gesture itself. There is a paucity of research looking at action effects. It has been shown that the salient effects of observed actions can have an impact on infants learning about specific action-effect relations, thereby enhancing execution of actions generating salient features (Elsner & Aschersleben, 2003; Hauf, Elsner, & Aschersleben, 2004). An unsolved issue discussed here suggests that the salient feature of an observed action may capture more attention than the action itself and then end-state emulation may be more probable. If this latter possibility were true, the anticipation of action effects would lead to a less accurate copy of the original act.

The purposes of the present study were both theoretical and methodological: we hoped to assess the extent to which the goal-directed view applies to imitation of object-related actions in younger children. We followed the logic of the preceding studies with 17- and 29-month-old children. These two age groups were chosen for two reasons. First, there is a paucity of research by which to compare the performance of different age groups of children on the same imitation task. Second, this age range has long been a focus of imitation research in both developmental and comparative fields (Bellagamba & Tomasello, 1999; Call & Tomasello, 1995; Carpenter, Akhtar, & Tomasello, 1998; Carpenter et al., 2002, 2005; Horner & Whiten, 2005; Huang et al., 2002, 2006; Meltzoff, 1995; Nagell, Olguin, & Tomasello, 1993; Want & Harris, 2001; Whiten, Custance, Gomez, Teixidor, & Bard, 1996). We modified the dot task (Bekkering et al., 2000) to present two novel objects, which were mounted on a board at a distance of 25 cm from each other. Thus, the locations of the objects mirrored the right and left hands of the actor. Each object could be manipulated to display a distinctive end-state transformation and a salient feature of the outcome (e.g. flashes of light or a beeping sound). Children observed the experimenter perform a specific act with each of the two objects (pushing the disk downward or pulling the handle upward) in sequence unimanually with ipsilateral or contralateral arm movements. Then children were given a chance to manipulate the objects themselves. In each condition (unimanual ipsilateral vs. unimanual contralateral), half of the children observed the manipulatory acts only, whereas the other half observed the acts followed by their salient outcomes (salient vs. nonsalient).

If the manipulatory act takes precedence in the goal hierarchy, the goal-directed view predicts that substitution of contralateral for ipsilateral movement paths would occur more frequently on contralateral trials than on ipsilateral trials. If the perceived saliency augments the tendency to copy the observed act, performance should be more successful when a beeping sound or flashes of light accompany the act than when only the act itself is observed. If, however, the perceived salience captures more attention than the manipulatory act, errors in movement path selection would be relatively frequent when the salient features accompany the act. Lastly, if goal representation is a necessary component of the object-related imitation task and 29-month-old children are better able to infer intentions than 17-month-old infants, the imitative performance of the 29-month-old group should be better than that of the 17-month-old group.

Experiment 1

Method

Participants. The participants consisted of 64 17-month-old infants (38 boys and 26 girls; *M* = 17.21 months, *SD* = 0.83) and 64 29-month-old preschoolers (33 boys and 31 girls; *M* = 29.3 months, *SD* = 2.11). They were recruited from a number of health centers and hospitals in Hualien city. Some preschoolers were also recruited from local nurseries. All were ethnic Chinese in Taiwan, and had no known physical, sensory, or mental handicap. An additional 15 children (10 17-month-olds and 5 29-month-olds) were excluded from the final sample due to procedural error (4), failure to respond to both objects (5), fussing or crying (5) or mother s prompts (1).

Apparatus. Two novel objects were constructed specifically for the present study (Figure 1). Each object was mounted on top of a translucent box measured 25 × 25 × 10 cm. We stuck velcros to the bottom of the box so as to switch the objects to the right or left of a wooden board (45 × 25 cm) according to assigned position. To ensure that the board was firmly placed on the table, we also attached slip-resistant strips to the bottom of the board. The first object was a vertical disk (12 cm in diameter) that had a 1-cm round hole cut out of the center. The disk could be pushed downward through a 90-degree arc such that it touched a button (0.5 cm high) on the top surface of the box. The button activated a beeper inside the box when the disk reached its flat position. The second object was a metal handle (8 × 2 cm) that could be pulled upward. The handle activated decorative lights installed inside the box when it was pulled a distance of over 1 cm.

Test situation. All participants were tested individually at a laboratory in the Department of Human Development at Tzu Chi University. On arrival at the department, the child and parent stayed in the reception area adjacent to the test room. While the experimenter explained the procedure to the parent, an assistant used plastic toys to engage the child in a warm-up play. This lasted 15-20 minutes. When the child felt comfortable and was willing to play the give and take game with the experimenter, the child and the parent were led to the test room.

The child was seated in a high chair (or on parent s laps if favored by the child) in front of a table (90 × 160 cm) opposite the experimenter. The parent sat next to the child. Two digital camcorders, focusing on the head, hands, and torso of the child and the surface of the table, were fixed on a tripod and stood behind and to the right and left of the experimenter respectively. The videotapes from the left camcorder were used for scoring. The videotapes from the right camcorder were used only when an action could not be seen clearly on those from the left camcorder. Once the child was settled, the parent was instructed to remain neutral, not to interact with the child verbally or otherwise. The experimenter then placed the task set on the table, and the study began.

Prior to the demonstration, the experimenter called the child s name or used the vocal words look over here to gain his or her attention. Following the demonstration, the experimenter rotated the board 180 degrees, relocated it in front of the child, and said, it s your turn. Thus the locations of the two objects relative to the child s two hands were the same as they were to the experimenter. A 40-s response period was timed once the child first touched either object. In most cases, children spontaneously interacted with the objects one after the other. If the child persisted with a single object for more than 10s or three responses, they were directed to the other object by the experimenter pointing to the box and saying, see the other one? The experimental session lasted approximately 3 minutes. Compensation for participation included a toy and still photographs stored on CD.

Experimental design. Experiment 1 employed a mixed design with object (disk vs. handle) as the within-subjects variable and age (17-month-old vs. 29-month-old), movement path (ipsilateral vs. contralateral), and perceptual saliency (salient vs. nonsalient) as the between-subjects variables. The participants were randomly assigned to one of four conditions with 16 children from each age group per condition. The four conditions differed as to whether the two target actions were performed unimanually with ipsilateral or contralateral hand paths and whether or not the actions made their salient outcomes occur. An electrical device that switched the lights and beeper inside the box on or off controlled the saliency of the outcomes. Within each condition the two objects were presented in two different rows such that each object was seen equally often on the right or left of the board. Sequences for two actions and two hands were also arranged in two different orders such that each action and each hand occurred equally often in each position. The four conditions were: the Ipsilateral Salient, Contralateral Salient, Ipsilateral Nonsalient, and Contralateral Nonsalient conditions (see Figure 1).

Ipsilateral Salient condition. In this condition, children observed the experimenter perform each target action unimanually with the hand ipsilateral to the object. Both hands were put under the table prior to the demonstration, and each time

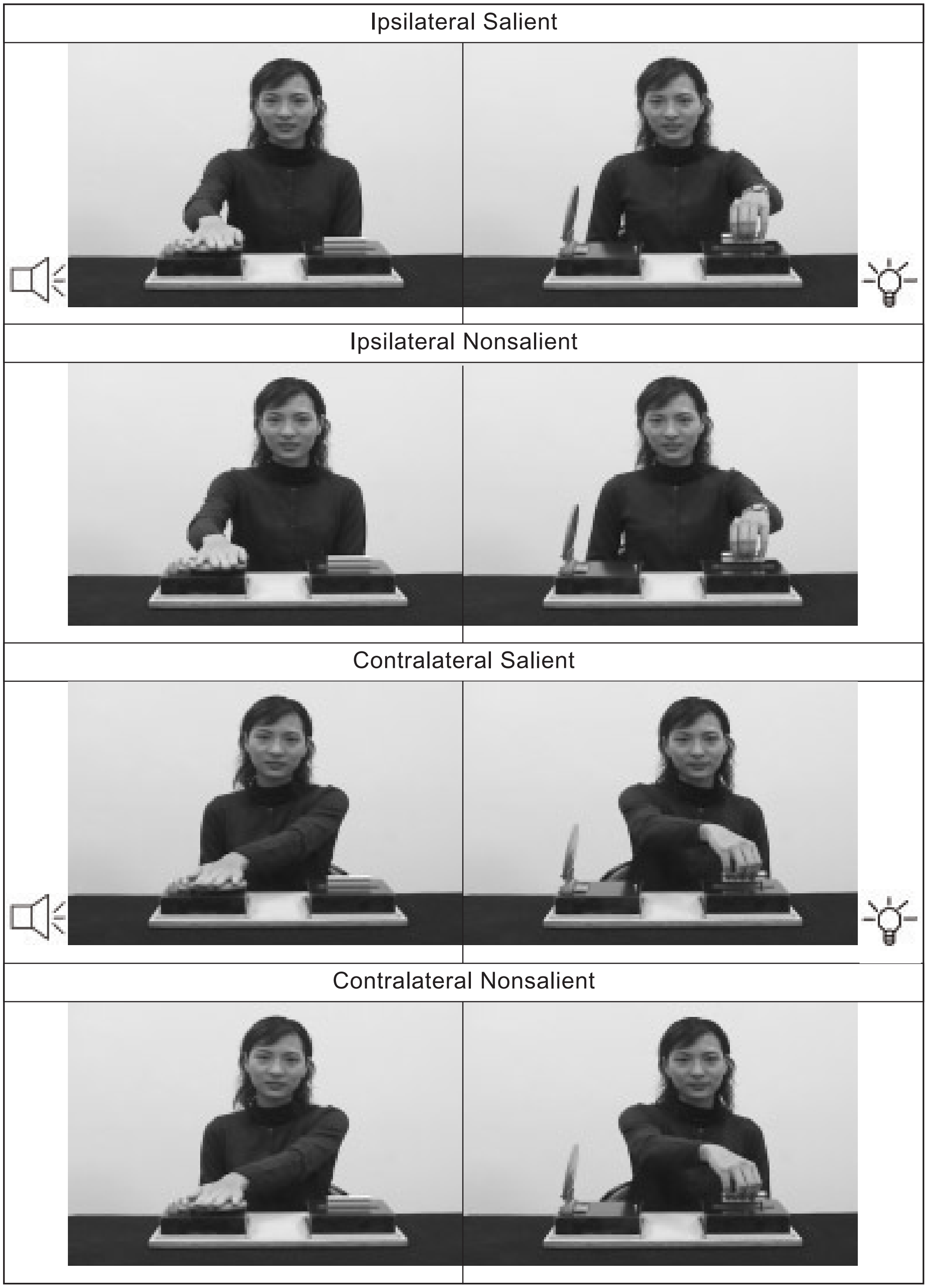


Figure 1. The experimental apparatus and four observational conditions.

after an action had been completed the experimenter returned the hand to the original position. For the disk, the experimenter pushed the disk downward from its upright position through a 90-degree arc such that it touched a button protruding from the top of the box. This activated the beeper inside the box, and the beeping sound lasted approximately 3 seconds (s). For the handle, the experimenter pulled the handle up to a distance of approximately 1.5 cm from the top of the box. This activated decorative lights inside the translucent box, and it was illuminated for approximately 3 s.

Ipsilateral Nonsalient condition. The actions and hand paths observed were identical to those in the Ipsilateral Salient condition. Because the batteries had been removed in advance, the salient effects of the actions were not activated.

Contralateral Salient condition. The actions and action effects observed in this condition were identical to those in the Ipsilateral Salient condition. However, children observed the experimenter perform each target action unimanually with the hand contralateral to the object.

Contralateral Nonsalient condition. The actions and hand movement paths presented in this condition were identical to those in the Contralateral Salient condition. Like in the Ipsilateral Nonsalient condition, however, the demonstrated actions did not activate their salient effects due to removal of the batteries.

Scoring. Children s responses to each of two objects were scored from the videotapes. Each response produced within the 40-s period was assigned a dichotomous yes/no code based on whether the target action of the object was performed. For the disk, a yes was coded if children pushed down the vertical disk so that it lay flat against the top of the box. It should be noted that a yes was not coded in the Ipsilateral Salient and Contralateral Salient conditions if children produced the pushing action but without activating the beeper. For the handle, a yes was coded if children pulled up the handle and the distance between its bottom and the top of the box was at least 1 cm. Like the disk, a yes was not coded in the Ipsilateral Salient and Contralateral Salient conditions if only the pulling action was replicated but without activating the light device. In addition, an ipsilateral/contralateral code was assigned to each of the coded responses in terms of its movement path.

Interrater reliability. A research assistant scored all participants responses. An undergraduate who was blind to the hypotheses of the study and the child s condition assignment was familiarized with the scoring criteria and independently scored 25% of the videotapes (32 sessions). Across both objects, Cohen s kappa was calculated yielding interrater reliabilities of k = .85 for target actions produced at the first act, k = .90 for all target actions produced in the 40-s response period, and k = 1.0 for movement path.

Results

The main analyses include: (1) mean target actions produced with the first touch of each object; (2) mean total number of target actions produced with each object in the 40-s response period. The scoring strategy followed by most developmentalists has been to record a dichotomous yes/no response based on whether the child produces the target action within a specified response period (e.g. Barr & Hayne, 1999; Devouche, 1998; Meltzoff, 1988a, b, 1995). We adopted a more conservative scoring criterion here by focusing on the response that children produced with their first touch of the object, as children produced several actions within the response period. Our rationale was that if an observer learns to perform an observed action by imitation, but not by trial and error, they should directly copy it at the first act (Heyes & Saggerson, 2002; Huang et al., 2002, 2006; Whiten et al., 1996). On the other hand, the current task involved a sequence of two distinct actions compared to conventional tasks that presented a single action. It remains to be shown whether in the present study exact recall of the physical details of the experimenter s actions would depend on more orienting responses before they were reproduced. Therefore, we also scored the number of target actions children produced during the response period as used by Aschersleben and colleagues (Elsner & Aschersleben, 2003; Hauf, Elsner, & Aschersleben, 2004). A comparison of performance at the first act and in the response period may provide some insight into how movement path or perceptual saliency was really at work in children s imitative responses.

Production of target actions at first act. Were children s first responses across each of both objects biased toward using a particular hand? In the 17-month-old group, 8 infants used the same hand (7 using the right hand; 1 using the left hand) and 56 used their respective hands (28 first manipulating the disk and handle using the right and left hands respectively; 28 showing the reverse), Binominal test (*P* = .5), $p < .001$. Similarly, 11 preschoolers in the 29-month-old group used the same hand (10 using the right hand; 1 using the left hand) and 53 used their respective hands (26 first manipulating the disk and handle using the right and left hands respectively; 27 showing the reverse), Binominal test (*P* = .5), $p < .001$. Thus, children did not exhibit hand preference with their first touch of either object.

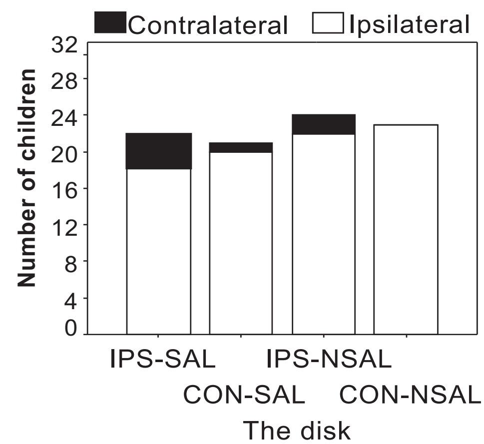
Table 1 gives mean target actions produced at the first act across items and conditions in each age group. The data were subjected to a 2 × 2 × 2 × 2 (object × movement path × perceptual saliency × age) mixed-model ANOVA. The analysis indicated a main effect of age, $F(1, 120) = 10.12$, $p < .01$, with no reliable effects of movement path, $F(1, 120) < 1$, or perceptual saliency, $F(1, 120) < 1$, or object, $F(1, 120) = 1.83$, $p = .18$. Overall, the 29-month-olds performed target actions as their first acts more often than did the 17-month-olds.

Table 1
Mean target actions produced at first act

Condition	17-month-old		29-month-old	
	Disk	Handle	Disk	Handle
IPS-SAL	.63 (.50)	.38 (.50)	.81 (.40)	.75 (.45)
IPS-NSAL	.69 (.48)	.63 (.50)	.81 (.40)	.75 (.45)
CON-SAL	.56 (.51)	.56 (.51)	.75 (.45)	.81 (.40)
CON-NSAL	.75 (.45)	.44 (.51)	.69 (.48)	.75 (.45)

Note. SDs are shown in parentheses. IPS-SAL, Ipsilateral Salient; IPS-NSAL, Ipsilateral Nonsalient; CON-SAL, Contralateral Salient; CON-NSAL, Contralateral Nonsalient.

Figure 2 gives the number of target actions at the first act, calculated in each condition, for children across both age groups, when they performed the actions with the ipsilateral hand and when they performed the actions with the contralateral hand. For the disk, only 4 participants responded with the contralateral hand. For the handle, only 9 participants responded with the contralateral hand. Clearly, regardless of conditions, there is an overall tendency in favor of using the ipsilateral hand.



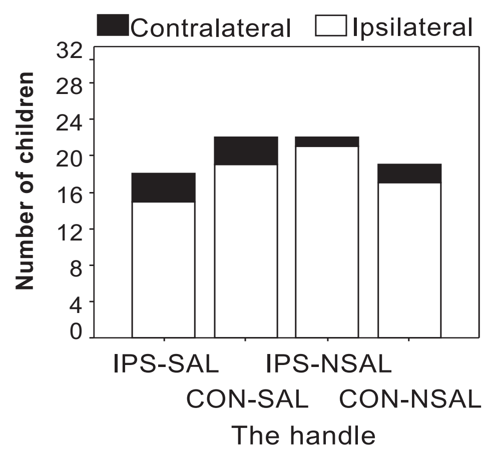


Figure 2. Number of children calculated across age groups for their first response to the disk or handle coded as producing the target action, when the action was performed with the ipsilateral hand and when the action was performed with the contralateral hand in the Ipsilateral Salient (IPS-SAL), Ipsilateral Nonsalient (IPS-NSAL), Contralateral Salient (CON-SAL), and Contralateral Nonsalient (CON-NSAL).

Production of all target actions in the response period. Was children s overall performance in the 40-s response period biased toward using a particular hand? Mean numbers of target actions (and standard deviations) calculated in terms of whether children responded with the left or right hand were as follows respectively: disk, 2.25 (2.61), 2.53 (3.39), t (63) < 1, and, handle, 1.59 (2.72), 1.42 (2.12), t (63) < 1, in the 17-month-old group; disk, 2.44 (3.38), 2.55 (3.04), t (63) < 1, and, handle, 2.14 (2.79), 2.48 (2.61), t (63) < 1, in the 29-month-old group. As in the first act analysis, children were not predisposed to use a particular hand in their production of target actions throughout the 40-s response period.

Table 2 presents mean numbers of target actions produced in the 40-s response period across items and conditions in each age group. A 2 × 2 × 2 × 2 (object × movement path × perceptual saliency × age) mixed-model ANOVA yielded main effects of object, F(1, 120) = 9.59, p < .01, and age, F(1, 120) = 5.51, p < .05, but no significant effects of movement path, F(1, 120) < 1, or perceptual saliency, F(1, 120) < 1. The main effects were qualified, however, by two higher-order interactions: object × age, F(1,120) =4.32, p < .05, and object × age × movement path, F(1, 120) = 4.92, p < .05. To evaluate the three-way interaction, perceptual saliency variable was collapsed across the Ipsilateral Salient and Ipsilateral Nonsalient conditions (ipsilateral trials), and across the Contralateral Salient and Contralateral Nonsalient conditions (contralateral trials). A 2 × 2 (object × age) mixed-model ANOVA was calculated separately for each collapsed condition.

In ipsilateral trial, the analysis indicated a main effect of object, F(1, 62) = 5.55, p < .05, a main effect of age, F(1, 62)= 4.25 ， p < .05, and a significant object × age interaction, F(1, 62) = 8.53, p < .01. As shown in Figure 3, the 29-month-old group produced a similar number of target actions with the disk as with the handle, t (31) < 1, whereas the 17-month-old group produced a higher number of target actions with the disk than they did with the handle, t (31) = 4.01, p < .001. It can be also seen that both groups produced a similar number of target actions with the disk, t (62) < 1, but the 29-month-old group had a higher number of target actions with the handle than the 17-month-old group, t (62) = 3.65, p < .01. In contralateral trials, the analysis failed to show main effects of object, F(1, 62) = 3.87, p = .055, or age, F(1, 62) = 1.58, p = .21, or a significant object × age interaction, F(1, 62) < 1.

Table 2
Mean total number of target actions produced in 40-s response period

Condition	17-month-old		29-month-old	
	Disk	Handle	Disk	Handle
IPS-SAL	4.75 (3.55)	2.38 (2.36)	4.81 (3.35)	4.25 (3.63)
IPS-NSAL	5.13 (3.10)	2.25 (1.77)	4.50 (2.78)	5.63 (1.96)
CON-SAL	4.50 (2.34)	4.00 (4.50)	4.00 (2.16)	4.50 (1.57)
CON-NSAL	4.63 (2.50)	3.38 (2.03)	6.56 (3.56)	4.13 (4.69)

Note. SDs are shown in parentheses. IPS-SAL, Ipsilateral Salient; IPS-NSAL, Ipsilateral Nonsalient; CON-SAL, Contralateral Salient; CON-NSAL, Contralateral Nonsalient.

Table 3 shows the proportions of target actions in the 40-s response period recoded as reproducing the same movement path as the experimenter. A 2 × 2 × 2 × 2 (object × age × movement path × perceptual saliency) mixed-model ANOVA revealed a main effect of movement path, F(1, 105) = 664.73, p < .001, and a significant object × movement path interaction, F(1, 105) = 4.20, p < .05. There were no reliable effects of object, F(1, 105) < 1, or age, F(1, 105) < 1, or perceptual saliency, F(1, 105) < 1. Again, perceptual saliency was collapsed into ipsilateral and contralateral trials. A two-tailed t test confirmed no significant object differences either in ipsilateral, t (55) = 1.23, p = .22, or contralateral trials, t (56) = 1.78, p = .08. The substantial rate of errors in hand selection during contralateral trials is striking compared to a relative tendency to follow the experimenter s hand path in ipsilateral trials. However, children under these two circumstances performed the target actions equally frequently.

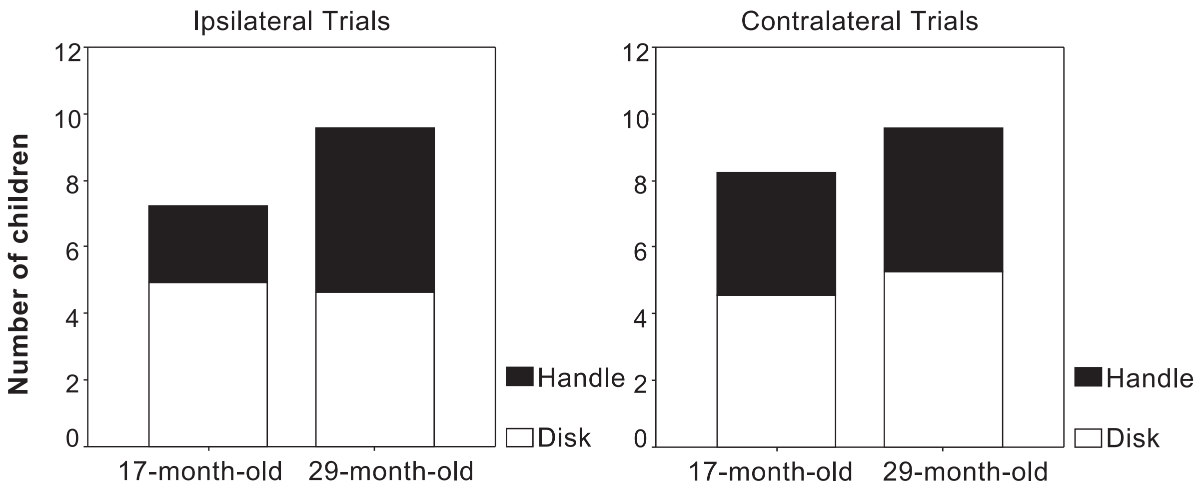


Figure 3. Experiment 1: Mean total number of target actions produced in 40-s response period for ipsilateral trials collapsed across the Ipsilateral Salient and Ipsilateral Nonsalient conditions and for contralateral trials collapsed across the Contralateral Salient and Contralateral Nonsalient conditions.

Table 3
Mean proportion of target actions in 40-s response period, recoded in terms of whether children reproduced the same movement path as the experimenter

Condition	17-month-old		29-month-old	
	Disk	Handle	Disk	Handle
IPS-SAL	89%	81%	91%	78%
IPS-NSAL	91%	93%	91%	90%
CON-SAL	5%	12%	4%	16%
CON-NSAL	1%	12%	6%	10%

Note. IPS-SAL, Ipsilateral Salient; IPS-NSAL, Ipsilateral Nonsalient; CON-SAL, Contralateral Salient; CON-NSAL, Contralateral Nonsalient.

Discussion

The present study showed the same pattern of errors in hand selection in 17- to 29-month-old children, as was found by Bekkering et al. (2000) in older children. Across conditions, children tended to act on each of two objects using the hand ipsilateral to the object. This ipsilateral tendency was not diverted by the action effects. Performance of target actions was also similar regardless of perceptual saliency. Hence, the salient effects did not capture more attention than the actions. Additionally, age-related differences were noted. Overall, preschoolers reproduced target actions as their first acts more often than did infants. Considering performance in the 40-s response period in ipsilateral trials, the frequency of reproductions with the handle by preschoolers was also high relative to that by infants for whom the frequency of reproductions with the disk was higher than that of the handle. Further, object differences in ipsilateral trials were revealed in infants, but not in preschoolers.

The goal-directed view derived from the hand-to-ear task suggests that children choose the correct ear at the expense of hand paths in response to contralateral actions because contralateral actions impose constraints on resources and under such circumstances the ear is encoded as dominant over the hand. Following this logic, a possible explanation for the infrequency of contralateral response in the present study may be that the ways of manipulating objects were represented as the higher goals in the hierarchy relative to the hand paths. Hence, when resources were assumed to be restricted in contralateral trials, children committed contra-ipsi errors to reenact the manipulatory actions.

However, there is an inconsistency in the rate of contra-ipsi errors between the hand-to-ear and object manipulation tasks. In the present study, the rates of hand substitution in children s production of target actions in the 40-s response period during contralateral trials were 96% (the disk) and 88% (the handle) across both age groups compared to the rate of 48% in the Bekkering et al. (2000) study. One possible explanation for this may be that the current task and the hand-to-ear task are not comparable in task demands. In the hand-to-ear task, goals implemented a course of action that ended up with the hand touching one of two ears differing in location. By contrast, the current task specified two distinct objects differing in location and form of manipulation, and presumably included a greater number of goals and higher visuomotor complexity. These constraints appear inherent in an object-related task and to preclude the tendency to replicate contralateral responses during imitation.

On the other hand, object differences revealed in ipsilateral trials suggest that manipulation of the handle required more dexterity than that of the disk. This was suggested by an age-related improvement in performance of the handle when all target actions produced in the 40-s response period were counted. It should be noted that in the 17-month-old group performance of the disk was superior to performance of the handle, whereas no object difference was found in the 29-month-old group. Why were the effects of item revealed only in ipsilateral trials? A likely explanation is that the end-state transformation of the disk was salient, and led to results more interesting to infants. For example, the disk was rotated from an upright position to a flat position. This involved an angular displacement of 90 degrees. In contrast, the handle was pulled a distance of only 1.5 cm and its end-state transformation was probably less salient than that of the disk. Therefore, visuospatial characteristics of the disk were likely to promote a strong tendency in infants to reproduce its ipsilateral modeled manipulation because they benefited from a decrease in resource restriction.

Another explanation of age-related differences concerns the spatial constraints of the task. By design, the disk was positioned in a way that the experimenter pushed the spatially compatible side of the disk in ipsilateral trials (e.g. the right hand pushing the right side of the disk when it was positioned on the right of the board) and spatially incompatible side of the disk in contralateral trials (e.g. the right hand pushing the left side of the disk when it was positioned on the left of the board). In contrast, the experimenter always pulled the handle at its upper end regardless of its position. Therefore, it may be that the 17-month-olds manipulated the disk with relative frequency in ipsilateral trials due to spatial compatibility effects. The influence of spatial compatibility in the 29-month-old group was relatively insignificant perhaps because skills acquired by older children such as behavioral inhibition diverted their attention away from visuomotor and spatial properties of the disk.

If the disk required less dexterity than the handle, one would expect the goal-directed theory to reserve a slightly high proclivity to copy contralateral paths for manipulation of the disk. However, only 2% of the children who performed the target action with the disk copied the contralateral path as their first act compared to 8% of the children who did so with the handle. Considering all target actions produced in the 40-s period, the rates of contralateral responses were 4% (the disk) and 13% (the handle) in contralateral trials. As the task set consisted of two objects with different manipulations, it appears that a tendency to substitute contralateral hands is not simply due to a difficulty in manipulating a single object. Instead, it is more likely that children s strategy choice depends on the goal complexity determined by the overall difficulty level of the task set.

It is also worth noting that children were likely to perform the manipulation with the hand ipsilateral to the object. Very few of them chose a dominant hand across objects. Experiment 2 was designed to further explore why children s hand selection is preferentially based on two different hands.

Experiment 2

A preference for the hand ipsilateral to the object site in Experiment 1 might be explained by two possible explanations.

A first possibility is that the overall ipsilateral preference was due to resource constraints on the process of generating goal-directed responses. According to the goal-directed theory, imitation of contralateral movements was less accurate because their visuomotor complexity was assumed to be high relative to that of ipsilateral movements and movement paths were represented as goals initially lower in the hierarchy. In addition, by design, the experimenter acted on each of two objects with a different hand. Seeing two different hands may have from the outset imposed constraints on execution of contralateral responses.

Resting on the intentionality-based theory, a second explanation is that children watched the experimenter manipulate each object unimanually with a different hand, thereby learning switching hands as a strategy intended by the experimenter. In support of this, Gergely, Bekkering, and Kir ly (2002) reported that 14-month-oldss use the constraints of situations to evaluate an adult s intentional stance and differentially copy body movements. They had an adult illuminate a light box by touching the forehead to the box s top. It was found that 69% of infants copied the unfamiliar response when the adult performed the head touching with two hands lying on the table (hands free) compared to only 21% when the adult performed the action with the torso and hands wrapped in a blanket (hands occupied). Infants thus used the task constraints to distinguish the head touching in the hands free condition (purposeful) from that in the hands occupied condition (no choice but to lower the head down).

The purpose of Experiment 2 was to examine the goal-directed and intentionality-based hypotheses for explaining the overall ipsilateral preference observed in Experiment 1. Participants in Experiment 2 were presented with the Experiment 1 task, but watched now the experimenter manipulate a sequence of two objects using the same hand. Following the logic of the Gergely et al. study, we displayed the actions with two modifications. During the presentation period, children could see the experimenter s spare hand either hold a cup by its handle (hand-occupied) or stay empty (hand-free). The manipulations demonstrated in Experiment 2 always triggered the salient outcomes the objects afforded.

The goal-directed hypothesis postulates that resource competition prevents a faithful duplication under limited resources. If our modifications reduce the complexity imposed on the implementation of the components, one would expect children to be biased toward using a dominant hand in both conditions. Accordingly, the relative ipsilateral preference found in Experiment 1 would become less significant. If, however, our modifications do not diminish the goal complexity inherent in the task, this ipsilateral preference should persist across conditions. On the other hand, the intentionality-based hypothesis assumes that the intention to copy body movements entails a capacity to encode the constraints on an agent in relation to the intentional stance. If children are more motivated to reenact the intended means, one would expect them to differentially adopt the one-handed or two-handed strategy in the hand-free and hand-occupied conditions.

Method

Participants. The participants were 32 17-month-old infants (18 boys and 14 girls; M = 17.72 months, SD = 1.15) and 32 31-month-old preschoolers (15 boys and 17 girls; M = 31.5 months, SD = 1.33). They were recruited in the same manner as Experiment 1. An additional 2 children (1 in the 17-month-old group and 1 in the 31-month-old group) were excluded from the final sample due to procedural error.

Apparatus. The test objects and their setup were the same as those used in Experiment 1. There was an additional cup (8.5 cm in diameter and 11.5 cm in height) that could be picked up by a handle attached to and extending outward from the cup.

Experimental design. Experiment 2 adopted a mixed design in which object (disk vs. handle) was the within-subjects variable, and age (17-month-old vs. 31-month-old) and task constraints (hand-occupied vs. hand-free) were the between-subjects variables. There were two observational conditions in the study: the hand-occupied and hand-free conditions (Figure 4). In both conditions, while the experimenter manipulated each of two objects unimanually with the same hand, the other hand is held at chest height at a distance of about 5 cm from chest. The experimenter s bodily configurations children saw in these two conditions were identical. What differed was whether, during demonstration, children observed this hand grasping the cup handle (hand-occupied) or remaining unused (hand-free).

In the hand-occupied condition, the cup was positioned adjacent to the board s left edge when the experimenter used the left hand, and to the board s right edge when she used the right hand. First, the experimenter grasped the cup and lifted it at chest height. Next, she used the other hand to display the two target actions in sequence. The sequence was repeated twice in approximately 40s. The experimenter s both hands were put under the table prior to the demonstration. Each time she completed an action the hand returned to its initial position. At the end of the presentation period, she withdrew the cup, rotated the board 180 degrees, and presented it on the table in front of the child. In the hand-free condition, the modelling procedure was identical to that described in the hand-occupied condition, except that the hand lifted at chest height was left empty without grasping things.

The participants were randomly assigned to one of two conditions with 16 children from each age group per condition. Within each condition the two objects were presented in two different rows such that each object was seen equally often on the right or left of the board. Sequences for two actions were also counter-balanced. Half of the children in each condition watched the experimenter perform the

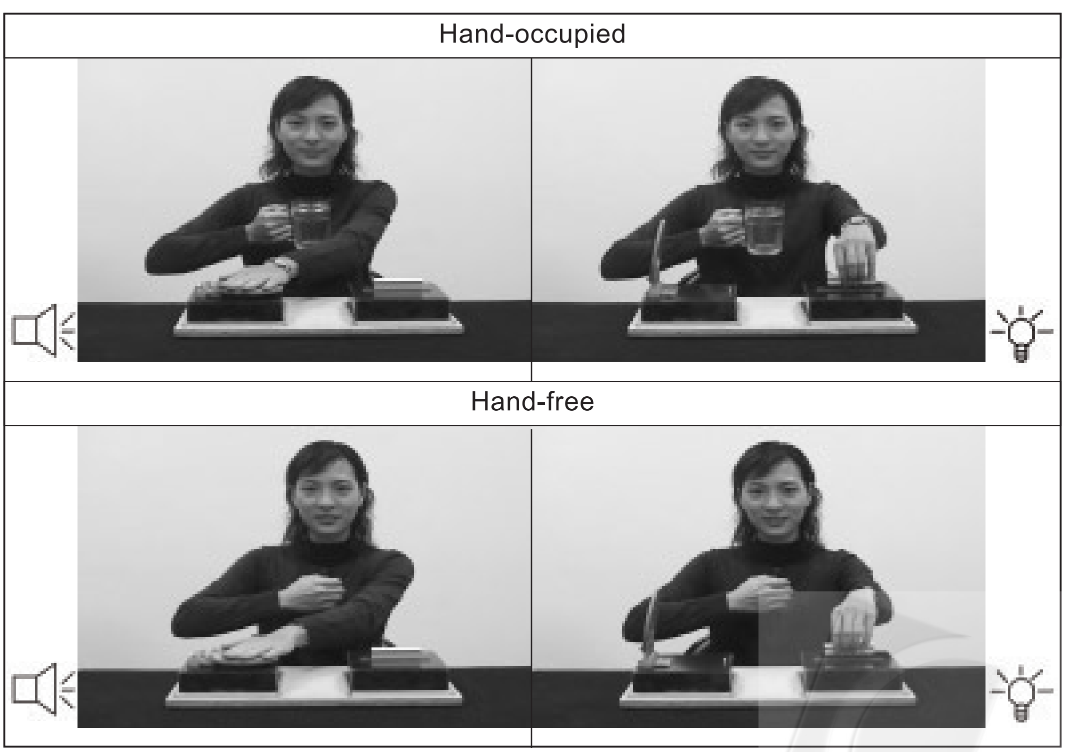


Figure 4. The experimental apparatus and two observational conditions.

actions with the right hand; the other half watched the actions performed with the left hand.

Test situation. The test situation, including the placement of the camcorders, the warm-up procedure, and the instructions for children and parents, was identical to that described in Experiment 1.

Scoring. The scoring procedure and criteria followed those described in Experiment 1.

Interrater reliability. As in Experiment 1, the research assistant scored all participants responses. Another undergraduate who was blind to the hypotheses of the study and the child s condition assignment was familiarized with the scoring criteria and independently scored all videotapes (64 sessions). Across both objects, interrater reliability using Cohen s kappa was *k* = .97 for target actions produced at the first act, and *k* = .88 for all target actions produced in the 40-s response period.

Results

As in Experiment 1, the main analyses include: (1) mean target actions produced at the first act; (2) mean total number of target actions produced in the 40-s response period.

Production of target actions at first act. Were children s first responses across each of both objects biased toward using a particular hand? In the 17-month-old group, 6 infants used the same hand (all using the right hand) and 26 used their respective hands (13 first manipulating the disk and handle using the right and left hands respectively; 13 showing the reverse), Binominal test ($P = .5$), $p = .001$. In the 31-month-old group, 5 preschoolers used the same hand (3 using the right hand; 2 using the left hand) and 27 used their respective hands (15 first manipulating the disk and handle using the right and left hands respectively; 12 showing the reverse), Binominal test ($P = .5$), $p < .001$. Children thus did not display preference for a particular hand with their first touch of either object.

Mean target actions produced at the first act for each item, condition, and age group are shown in Table 4. A 2 × 2 × 2 (object × age × task constraints) mixed-model ANOVA revealed no reliable effects of object, $F(1, 60) = 2.47$, $p = .12$, or age, $F(1, 60) < 1$, or task constraints, $F(1, 60) = 1.67$, $p = .20$.

Table 4
Mean target actions produced at first act

Condition	17-month-old		31-month-old	
	Disk	Handle	Disk	Handle
Hand-occupied	.75 (.45)	.56 (.51)	.75 (.45)	.56 (.51)
Hand-free	.50 (.52)	.56(.51)	.69 (.48)	.44 (.51)

Note. SDs are shown in parentheses.

Figure 5 gives the number of children, calculated across age groups, for their first response to each of two objects coded as producing the target action, when they used the same hand (one-handed strategy) and when they used two different hands (two-handed strategy). As shown in Figure 5, there is a bias toward the two-handed strategy in the hand-occupied condition, Binominal test ($P = .5$), $p < .01$. The bias was not significant in the hand-free condition, Binominal test ($P = .5$), $p = .29$, perhaps due to the relatively low number of children who succeeded in performing both target actions as their first acts in this condition. Additionally, collapsed across condition, an overall bias in favor of using two different hands was confirmed, Binominal test ($P = .5$), $p < .01$. Inspection of the data makes it clear that these children who adopted the two-handed strategy also performed each target action with the hand ipsilateral to the object.

Production of all target actions in the response period. Did children base their overall performance in the 40-s response period on preference for a particular hand? Mean target actions (and standard deviations) calculated in terms of whether children responded with the left hand or right hand were as follows respectively: disk, 2.56 (4.61), 2.38 (2.67), $t(31) < 1$, and, handle, 1.41 (2.31), 2.00 (2.60), $t(31) < 1$, in the 17-month-olds group; disk, 1.59 (1.93), 3.22 (6.28), t (31) = 1.26, p = .22, and, handle, 1.91 (2.35), 1.88 (1.93), t (31) < 1, in the 31-month-olds group. Overall, children

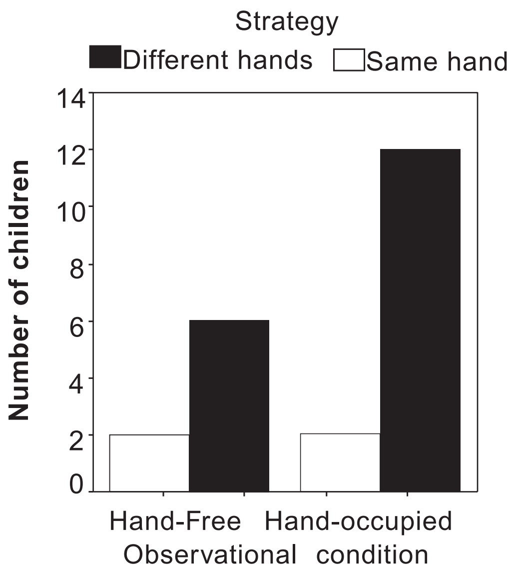


Figure 5. Number of children calculated across age groups for their first responses to two objects coded as producing target actions, when both actions were performed with the same hand and when both actions were performed with two different hands.

used the right hand and left hand equally often in their production of target actions throughout the 40-s response period.

Table 5 presents mean numbers of target actions produced in the 40-s response period across items and conditions in each age group. A 2 × 2 × 2 (object × age × task constraints) mixed-model ANOVA indicated no main effects of object, F (1, 60) = 3.57, p = .064, or age, F (1, 60) < 1, or task constraints, F (1, 60) < 1.

Table 6 shows proportions of target actions in the 40-s response period, calculated across objects in terms of whether they were performed with the same hand as the experimenter. A 2 × 2 × 2 (age × task constraints × experimenter s hand) mixed-model ANOVA failed to indicate reliable effects of age, F (1, 56) < 1, or task constraints, F (1, 56) = 1.40, p = .24, or experimenter s hand, F (1, 56) = 2.34, p = .13. As can be seen in Table 6, in the hand-occupied condition the 31-month-olds appear more likely to respond with the right hand when the experimenter used the left hand. However, a two-tailed paired t test did not confirm a significant difference between the tendency to use the right hand and the tendency to use the left hand within the 31-month-old group, t (7) = 1.59, p = .16. As in Experiment 1, children exhibited a strong ipsilateral preference in their overall performance of target actions in the 40-s response period.

Table 5
Mean total number of target actions produced in 40-s response period

Condition	17-month-old		31-month-old	
	Disk	Handle	Disk	Handle
Hand-occupied	4.81 (2.74)	3.69 (3.63)	5.75 (7.94)	3.81(2.29)
Hand-free	5.06 (5.13)	3.13 (3.10)	3.88 (2.00)	3.75(2.24)

Note. SDs are shown in parentheses.

Table 6
Mean proportion of target actions across objects in 40-s response period, recoded in terms of whether children responded with the same hand as the experimenter

Condition	Model s hand	17-month-old	31-month-old
Hand-occupied	Left hand	.43 (.24)	.30 (.35)
	Right hand	.57 (.39)	.45 (.15)
Hand-free	Left hand	.52 (.41)	.45 (.29)
	Right hand	.57 (.34)	.59 (.25)

Note. SDs are shown in parentheses.

Discussion

Unlike experiment 1, age-related differences were not found at the first act or when the total number of target actions in the 40-s response period was scored. Neither were the effects of task constraints. As in experiment 1, children showed a proclivity to perform each target action with the hand ipsilateral to the object. They did not differentially copy the one-handed strategy in either condition. The insignificance of these results shows that children did not use the constraints of the situation to identify information about the intentional stance motivating the experimenter s behavior. Why did children not differentially respond to the task constraints? Here we explore some possible explanations.

First, we can rule out mimicry as an explanation, given that virtually no children reproduced the unfamiliar gesture of lifting a hand at chest height. If they literally copied the experimenter s body movements, they should have preferred not to switch hands and therefore reenacted this unfamiliar action.

An explanation based on the goal-directed theory is that children represented the manipulatory actions as dominant over the strategy, thereby enabling an overall ipsilateral preference. In either condition, the demonstration, by design, included a sequence of one unimanual ipsilateral response and one unimanual contralateral response. The visuomotor complexity of the latter was initially assumed to be higher than that of the other. Therefore, it is plausible that children preferred to substitute a contralateral response at the cost of the one-handed strategy due to resource restriction. The ignorance of the experimenter s strategy is striking given the constraints of the situation put on her intentional stance. The task constraints appeared not to reduce the goal complexity inherent in the Experiment 1 task.

A third explanation is that the task constraints were not noticeable enough to encourage children to perceive the experimenter s strategy in relation to information about the intentional stance. This could be because the efficiency in performing the manipulations was similar for the one-handed strategy as for the two-handed strategy. Recall that in the hands free condition in the Gergely et al. (2002) study, a blanket wrapped around the hands and torso of the demonstrator who was forced to touch the forehead to the panel of the box. Under such a situation, the head touching could not be substituted by other behavioral modalities and presented a sensible as well as efficient strategy. Thus, in the present study, children did not interpret the task constraints as the intentional stance underlying the observed behavior perhaps because the efficiency for the one-handed strategy was not distinct from that for the two-handed strategy. Furthermore, lifting a hand in front of chest was initially designed to highlight the availability of resources and to control for the consistence of the bodily configuration between the hand-free and hand-occupied conditions. Nevertheless, it remains to be shown whether children interpreted such a bodily configuration as some kind of meaningful gesture instead of clues to the intentional stance.

On the other hand, one possible explanation for the lack of age differences might be an increased susceptibility to intention cues on the part of the 31-month-olds who had been distracted toward the experimenter s behavior as cues to the intentional stance. In contrast to the 29-month-olds performance in Experiment 1, the slightly lower performance by the 31-month-olds in Experiment 2 could have been due to the increased task requirements for encoding intention. Contrarily, the younger groups in both experiments exhibited similar performance. We interpret this as showing that the infants were not as sensitive to the experimenter s behavior as were the preschoolers, thereby distracted away from interpreting the task constraints. This notion is supported by a positive developmental trend in the ability to mimic that has been reported in this age range (Huang et al., 2006).

To sum up: the current results are not conclusive; the question of whether the overall ipsilateral preference is due to resource competition (the goal-directed theory) or failure to identify the intentional stance (the intentionality-based theory) warrants further investigation. One interesting area to consider in future research is to manipulate task constraints in a more natural situation. This could be achieved, for example, in the hand-occupied condition, by having one hand wrapped up in a bandage and informing children that the experimenter is suffering a hand injury, prior to testing. In the hand-free condition, a more sensible way to emphasize resource availability may be to place the unused hand flat on the table, as in the Gergely et al. study, instead of raising it up. These modifications may be more feasible for guiding children to interpret task constraints in relation to the underlying intentional stance. Another important area for future research is to determine the comparability between the demonstration and the observation conditions. Recall that in the hand-occupied condition, the experimenter after demonstration gave children the task set only but without the cup. Would children become more likely to reenact the one-handed strategy if the experimenter presents both the task set and cup in front of them? This is a question worth pursuing.

General Discussion

The goal-directed theory suggests that imitation entails analysis of an observed action into a set of components that comprise the hierarchy of goals of varying functionality. It specifies a substitution of the lower goals for the higher goals when resources are limited. Assuming that a manipulatory action and its effect would be dominant over a hand path, we used a novel task derived from the goal-directed imitation research to assess imitation of object manipulation in two samples of young children. In Experiment 1, the experimenter switched hands and manipulated two objects in sequence with unimanual ipsilateral or contralateral hand paths. In Experiment 2, the experimenter manipulated the two objects with the same hand. In both experiments, children displayed an overall preference to reenact the manipulations with ipsilateral hands, and committed more errors in hand selection (or strategy choice) than in imitating these actions.

This pattern of findings provides some evidence for the goal-directed hypothesis. However, this is subject to another possibility that the object motion generated as part of the manipulation attracts children to the object s dynamic affordances, leading them to emulate. Emulation presents an alternative explanation for any act that involves manipulating objects. This parsimonious position need not rest on the goal hierarchy, because children could simply react to knowledge about the object affordances. Nonetheless, we cannot rule out that a tendency to follow hand paths of unimanual ipsilateral movements was due, not to emulation learning, but to a decrease in the goal complexity. If participants were entirely ignorant of the experimenter s strategy, ipsilateral and contralateral hand paths should have been randomly selected. The rare occurrence of contralateral responses possibly reflects the problem of resource overload inherent in the object manipulation task. Its high-level goal complexity might have precluded a tendency for contralateral responding, prior to observing the demonstration. Under this interpretation, a particularly high rate of contra-ipsi errors in the current work compared to that in the Bekkering et al. (2000) study may be due to execution constraints on the reconstruction of an observed action from its enlisted components.

Whether the results of the present study are due to resource competition, or to a tendency to emulate, they suggest that at the root of both explanations lie the interpretative problems that have arisen from the demanding nature of our task. Under the goal-directed interpretation, they show that resource overload restricts movements of the contralateral hands. Under the alternative account, they imply that because object movement induces affordance detection diverting attention away from body movement, learning how to manipulate objects does not necessarily implement a hand selection process.

Beyond our attempt to clarify the generality of the goal-directed theory, we ought to improve the comparability of results between the hand-to-ear task and the object manipulation task. For example, it may be appropriate to reduce the very high rate of contra-ipsi errors by diminishing the number of variables, such as a hand path, a location, an object, and a manipulatory action. When the pattern of incorrect responding in the object manipulation task closely mimics that in the hand-to-ear task, this may best serve as evidence of resource competition. Then, we may proceed to compare the adequacy of the goal-directed and intentionality-based imitation theories by introducing intentional cues to the task. Alternatively, it may be appropriate to assess the processing of goal representation by repeating the current study with older preschool children. If they are better able to perceive the enlisted components, a similar pattern of incorrect hand movement paths should be produced in the object manipulation task as in the hand-to-ear task.

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動作路徑、知覺顯著性、與作業限制條件對嬰幼兒模仿物體操作的影響

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目標導引的模仿理論認爲：動作包含不同的要素，要素在模仿過程中以階層關係重組爲主要目標和次要目標。當資源有限時，和動作終點相較之下，手臂路徑易於在模仿中被犧牲。本研究設計兩個實驗，探討目標導引理論是否延伸於解釋嬰兒和學齡前兒童在物體操作作業的模仿表現。在實驗一，示範者以不同的手依次操作不同的物體，有些受試者觀察示範者使用與物體同側的手，有些觀察示範者使用與物體異側的手，其中二分之一的受試者觀察操作動作伴隨顯著的知覺效果，另二分之一只觀察操作動作。在實驗二，示範者改以同一手依次操作不同的物體，另一手握持杯子或閒置不用停放於胸前。結果發現：在兩個實驗中，受試者最傾向使用不同的手操作與手同側的物體，動作結果的顯著性或作業的限制條件並無法降低同側路徑的反應傾向。相較於Bekkering等（2000）的研究發現，異側路徑的反應傾向在本研究相當罕見。目標導引的過程是否干擾異側路徑和行爲策略的重演傾向，本研究尚未達成結論，因模仿物體操作可能比模仿身體動作引起更多固有的限制條件。

關鍵詞：模仿、目標導引的模仿、瞭解意圖、工具使用、動作表徵