HHS Public Access
Author manuscript
Dev Sci. Author manuscript; available in PMC 2018 June 15.

Published in final edited form as:
Dev Sci. 2008 July ; 11(4): 487–494. doi:10.1111/j.1467-7687.2008.00694.x.

Do as I do: 7-month-old infants selectively reproduce others' goals

J. Kiley Hamlin, **Elizabeth V. Hallinan**, and **Amanda L. Woodward**
Department of Psychology, University of Chicago, USA

Abstract

In the current study, we tested whether 7-month-old infants would selectively imitate the goal-relevant aspects of an observed action. Infants saw an experimenter perform an action on one of two small toys and then were given the opportunity to act on the toys. Infants viewed actions that were either goal-directed or goal-ambiguous, and that represented either completed or uncompleted goals. Infants reproduced the goal of the experimenter only in those cases where the action was goal-directed, in both the complete and incomplete goal conditions. These results provide the first evidence that infants as young as 7 months of age selectively imitate actions based on their goal-directedness, and that they are able to analyze the goals of even uncompleted actions. Even during the first year of life, infants' sensitivity to goal-directed action is expressed not only in their responses in visual habituation procedures, but also in their overt actions.

Introduction

Intentions are as real to us as the physical bodies they inhabit. When we observe others' behavior, motions through space are interpreted in terms of their intentional, rather than physical, nature. Reading beyond these physical properties of action is to their underlying goal structure allows us to interact with, reason about, and learn from social partners. Research has begun to elucidate children's growing access to this aspect of the social world (Bekkering, Wohlschlager & Gattis, 2000; see Baldwin & Baird, 2001; Zelazo, Astington & Olson, 1999; Malle, Moses & Baldwin, 2001, for reviews), and recent studies have sought the earliest developmental origins of this ability (e.g. Behne, Carpenter, Call & Tomasello, 2005; Gergely & Csibra, 2003; Johnson, 2000; Luo & Baillargeon, 2005; Somerville, Woodwad & Needham, 2005; Woodward, 2005).

Evidence from the visual habituation paradigm indicates that infants in the first year of life represent observed actions in terms of their goal-directed structure (Csibra, Gergely, Biro, Koos & Brockbank, 1999; Kiraly, Jovanovic, Prinz, Aschersleben & Gergely, 2003; Luo & Baillargeon, 2005; Woodward, 1998, 2005). Woodward (1998) showed 6-month-old infants events in which a person reached for and grasped one of two toys. Following habituation to this event, infants produced a robust novelty response (longer looking) on test trials in which the person moved her arm through the same path to grasp the other toy, but no such response

Address for correspondence: J. Kiley Hamlin, Department of Psychology, Yale University, 2 Hillhouse Ave, New Haven, CT 06520, USA; kiley.hamlin@yale.edu.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

when the person moved in a new way to grasp the same toy as during habituation. That is, infants responded selectively to disruptions in the agent–goal relation and ignored changes in the agent's path of motion. Under comparable conditions, infants did not represent the motions of inanimate objects (Jovanovic, Kiraly, Elsner, Aschersleben, Gergely & Prinz, 2002; Woodward, 1998) or unfamiliar human movements in this way (Woodward, 1999; see also Guajardo & Woodward, 2004), suggesting that this paradigm taps infants' propensity to encode actions in terms of agent–goal relations rather than simply relations between moving entities.

In addition to visual habituation procedures, imitation procedures have provided a valuable window into young children's action representations. Imitation, broadly defined as the reproduction of observed behaviors, is informative because typical actions represent multiple components that might be imitated. For one, actions involve physical movements. Actions also have goals, or desired outcomes, that are attained by those movements. Mature observers represent event goals at multiple levels of abstraction. For example, the movement of grasping a spoon could be represented as the immediate goal of obtaining the spoon, or at the higher-level goal of baking a cake. When observers imitate actions, they might reproduce all or only a few of these components, depending both on their understanding of each component and the importance they assign to it.

The propensity to selectively reproduce the goal-relevant components of actions is robust during the second year of life. Fourteen- to 18-month-olds are less likely to imitate motions that are apparently accidental than those that are marked as purposeful (Carpenter, Akhtar & Tomasello, 1998). By 18 months, children reproduce the intended outcomes of unsuccessful attempts despite not having seen them occur (Meltzoff, 1995; see also Bellagamba & Tomasello, 1999; Johnson, Booth & O'Hearn, 2001). Further, children at this age selectively reproduce the goal of an action while varying the means, so long as there is a clear end-state goal (Carpenter, Call & Tomasello, 2005; Gergely, Bekkering & Kiraly, 2002).

How early can the propensity to imitate other people's goals be traced? Imitation of bodily movements has been documented in newborn infants (Meltzoff & Moore, 1977; Meltzoff, 2004), and imitation of movements involving objects has been found by 6 months of age (Collie & Hayne, 1999; von Hofsten & Siddiqui, 1993). However, these reports do not provide direct evidence as to whether young infants selectively imitate the goal-relevant aspects of actions. The current studies investigated this question. Study 1 sought to replicate prior habituation findings using imitation as a response. Studies 2 and 3 used the imitation method to investigate a new question: whether young infants can discern the goal of an incomplete action.

In each study, we showed 7-month-old infants a goal-directed action, grasping or reaching toward one of two objects. Our question was whether infants would reproduce the goal and grasp the same object as the experimenter. To control for the possibility that infants' responses were driven solely by having their attention drawn to one of the toys, control groups observed manual actions that infants at this age do not respond to as goal-directed in habituation studies. In Study 1, this gesture was static contact with the back of the hand (Woodward, 1999). In Studies 2 and 3, we used pointing, a gesture that is understood as

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

goal-directed by older infants, but not younger ones (Sodian & Thoermer, 2004; Woodward & Guajardo, 2002).

Study 1

Method

Participants—Thirty-two full-term 7-month-old infants participated in the first study.[1] Sixteen infants (eight girls and eight boys; mean age = 6;28) saw the experimenter reach toward one of two toys and grasp it (*grasp condition*) and 16 (eight girls and eight boys; mean age = 7;1) saw the experimenter place the back of her hand on one of two toys (*back of hand condition*).[2]

Procedure—Infants sat at a table on their parent's lap, 76 cm from the experimenter. The procedure began with a warm-up phase in which each of the 12 experimental toys was briefly presented to the infants.[3]

During imitation trials the toys were presented in pairs, 38 cm apart from one another centered on a rectangular 76 cm × 25 cm black laminated board. To start the demonstration, the experimenter placed the board directly in front of her on the table, out of reach of the infant. She first ensured that the infant looked at each of the two toys, snapping behind each one if necessary to direct the infant's attention to it. Then, she called the infant's attention to herself, briefly making eye contact, and demonstrated the grasp or back of hand action, holding eye and hand contact with the toy for 5 seconds. In each condition, she accompanied her actions with the same verbalizations, saying 'Hi! [looking at the baby] Look! [turning to look at the goal toy] Oooh! [reaching toward the toy]'. The experimenter reached contralaterally (across the body, to the opposite side as hand) in the grasp condition and ipsilaterally (same side as hand) in the back of hand condition (see Figure 1). This resulted in gestures that were approximately matched in how they partially occluded the toy. After the demonstration, the experimenter withdrew her hand, called the infant to establish eye contact, and then pushed the tray forward to within the infant's reach while saying 'Now it's your turn!' If the infant did not grasp or touch a toy within 15 seconds the trial was excluded from the analysis.

This procedure was repeated for six trials with a new pair of toys presented on each trial. Each infant saw the toy pairs in a different random order. The experimenter alternated reaching to the toy on the right and the toy on the left. The side to which she reached on the first trial was counterbalanced in each condition.

---

[1]Eight additional infants began the procedure but were excluded from the sample because there was a procedure error ($n = 2$) or because they chose objects on only one side on all six trials ($n = 6$).

[2]Infants were from a large city in the United States. They were 50%white, 27% African American, 10% Hispanic, 3% Asian and 10%other. Parents had been contacted through mailings and advertisements and were offered $10 for participating.

[3]The toys each measured approximately 3 × 3 inches and were relatively easy for infants to pick up. Each infant saw the following pairs: (1) a red car and a striped ball, (2) a zebra and a pink car, (3) a green and blue dinosaur and a red boat, (4) a grey elephant and a blue car, (5) a red block and a grey and white dog, and (6) a leopard and a purple doll shoe. The order in which the pairs were presented was randomized and the position and goal status of the toys were counterbalanced.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Infants' responses were coded from the video record by coders who were uninformed about test condition as well as the goal toy in each individual trial. Because we sought to identify the infant's intended choice, we coded choices as the first toy the infant touched so long as contact was preceded by looking at and actively reaching for the toy. If an infant contacted a toy without first looking at it, and if this then resulted in the infant attending to the contacted toy, the trial was coded as a mistrial. We coded infants' responses based on the first toy they touched, rather than the toy they removed from the tray, because on some trials infants were unable to remove the toy (e.g. they pushed the toy away as they tried to grasp it).[4]

A second independent coder coded 30% of the babies, and the two coders agreed on 98% of the trials, Cohen's kappa = .96. To determine whether any differences in infant responding could be attributed to a difference in attention during the two different event types, infants' attention to each toy and to the experimenter during the demonstration was coded using a digital coding program (Aronson, 1999; Mangold International, 1998).

Results

Table 1 summarizes infants' responses. For each infant, we calculated the proportion of trials (excluding mistrials) on which the infant selected the toy that had been the target of the experimenter's action. These scores were then compared to chance (50%). Infants in the grasp condition systematically chose the toy that had been the experimenter's goal, mean proportion goal choice trials (SEM) = .63(.06), $t(15) = 2.37$, $p < .05$, $\eta^2 = .27$. In contrast, infants in the back of hand condition chose randomly, mean proportion goal choice trials (SEM) = .51(.05), $t(15) = .11$, $p = .91$, $\eta^2 = 0$. Infants in the grasp condition were reliably more likely to select the goal toy than were infants in the back of hand condition, $t(30) = 1.75$, one-tailed $p < .05$, $\eta^2 = .17$.[5]

Infants in the two conditions differed in their propensity to select the experimenter's goal. Could the extent to which the two modeled actions directed infants' attention to the targeted toy explain this behavior? Infants may have been more interested in the contralateral versus the ipsilateral reach type, or in grasping versus back of the hand contact with the toy, accounting for increased levels of imitation in the grasp condition. However, attention coding revealed no difference between the two conditions in infants' looking time to the target toy versus the non-target toy during presentation ($\text{Mean}_{\text{time target minus time non-target}}(\text{SEM})_{\text{grasp}} = 2.66(.43)$, $\text{Mean}_{\text{time target minus time non-target}}(\text{SEM})_{\text{back of hand}} = 2.67(.40)$; $t(30) = -.01$, $p = .99$, $\eta^2 = .000003$).[6] Furthermore, amount of looking toward the targeted toy was not reliably correlated with infants' tendency to choose that toy in either condition ($r_{\text{grasp}} = .07$, $p = .81$;

---

[4]Defining choice by the toy the infants first grasped and removed from the tray, despite producing a smaller set of codeable trials, yielded the same patterns of imitative results as first intentional touch (Study 1: Grasp versus chance, $p < .05$; Back of Hand versus chance, $p = .54$; Interaction, $p < .05$. Study 2: Unfulfilled Reach versus chance, $p < .05$; Point versus chance, $p = .27$; Interaction, $p < .05$. Study 3: Static Reach versus chance, one-tailed $p < .05$; Interaction, $p < .05$).

[5]Imitative patterns in Study 1 were reflected in individual patterns of response. In the grasp condition, 11 infants selected the goal toy on more than 50% of trials and three did so on less than 50% of the trials, sign test $p < .06$. In contrast, in the back of hand condition, nine infants selected the goal toy on more than 50% of the trials and seven did so on less than 50% of the trials, sign test $p = .80$.

[6]In each experiment, the reliability of the attention measure was assessed by having a second independent observer code 30% of the infants from each study. The second coder correlated strongly with the observations of the original coder; $r = .79$, .92, and .99 for Studies 1–3, respectively.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

$r_{\text{back of hand}} = -.26$, $p = .33$). These results suggest that infants' imitative responses in the two conditions were not driven by differences in the extent to which the two hand gestures entrained infants' attention on the targeted toy.

Discussion

When infants saw a familiar goal-directed action, grasping, directed at one of two toys, they systematically directed their own subsequent reaches to the same goal. When they saw an ambiguous action, static contact with the back of the hand, they did not direct their actions to the target toy. The two modeled movements were equally effective at drawing infants' attention to the target object, but infants responded differently to them, reproducing the goal for the grasp but not the back of hand movement. These results converge with visual habituation findings and provide the first evidence that infants younger than 1 year of age not only attend to, but also selectively reproduce, the goal-relevant parts of actions.

Although the two hand gestures in Study 1 were equivalent in their effects on infants' attention, and were designed to equate the extent to which the hand obscured the toy, they did involve physically different arm movements (contra- vs. ipsilateral reaches). In Studies 2 and 3, we eliminated this potential confound, and extended the paradigm to investigate a heretofore undocumented aspect of young infants' action knowledge – the ability to discern the goals of incomplete actions.

A central component of mature knowledge is that goals exist independently of the particular actions they drive (Meltzoff, 1995; Tomasello, Carpenter, Call, Behne & Moll, 2005; Woodward, 2005). Indeed, often goal-directed actions are carried out unsuccessfully, and using the outcome of these actions to determine their original goals would lead to mistakes. For example, believing that a basketball player who misses a jump shot aimed to put the ball into the stands would be a gross miscalculation of the situation. Adults, fortunately, rarely make mistakes such as these, as they are easily able to interpret the goals behind actions even when these goals go unrealized. It is less obvious, however, whether young infants possess this important piece of mature goal understanding. While infants in the first year of life seem to be able to extract the goal structure of completed actions, it is as yet not known whether infants at this age can also discern the goal of incomplete actions.

Several studies have documented this ability to interpret unfulfilled goals in older infants. Meltzoff (1995) found that 18-month-old infants imitated the goal of completed actions and apparent failed attempts at equal rates. For example, infants seemed to readily infer the unattained goal when an adult ‘mistakenly’ dropped an object just outside of a container or failed to insert a peg into a hole. They reproduced the intended action rather than the failed attempt. This finding was later replicated with 15-month-olds (Johnson *et al.*, 2001) but not with 12-month-olds (Bellagamba & Tomasello, 1999). Similarly, Behne and colleagues (2005) found that 9-month-olds, but not younger infants, responded appropriately and differentially to an adult who apparently tried, but failed, to give them a toy versus an adult who teased them and refused to give them a toy. These results suggest that there is a developmental progression in competence with unfulfilled goal states and support the possibility that young infants need outcome information in order to determine the goal of an action.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

The failures of younger infants in these studies might reflect an inability to understand unfulfilled goals in any circumstances. Alternatively, younger infants might have been confused by the relatively complex actions involved in these studies, and their understanding of unfulfilled goals might be evident in a simpler procedure. Study 2 examined this possibility using a paradigm like that in Study 1 except that the toys were beyond the actor's reach and she struggled unsuccessfully to attain the goal. As in Study 1, we compared this condition to a control condition in which infants viewed similar motions, but ones they would not readily represent as goal-directed. We used pointing as the control event because it is a familiar action; however, prior findings have shown that infants do not understand this action as being directed at objects until 9 to 12 months of age (Brune & Woodward, 2007; Sodian & Thoermer, 2004; Woodward & Guajardo, 2002). Because the amount of toy concealed was not an issue in this study, all reaches were ipsilateral.

Study 2

Method

Participants—Thirty-two full-term 7-month-olds participated in this study.[7] In the final sample, 16 infants (eight girls and eight boys; mean age = 6;29) saw the experimenter reach toward one of two toys and attempt but fail to reach it (failed reach condition) and 16 infants (eight girls and eight boys; mean age = 6;29) saw the experimenter point toward one of two toys (point condition).[8]

Procedure—The procedure was the same as in Study 1, with the following exceptions: The infant sat facing a long table (152 cm across). At the start of the procedure, the experimenter sat to the side of the table, near the infant, so that she could easily pass the infant the toys in the warm-up procedure. She then moved to the far side of the table, facing the infant for the imitation trials. A confederate, hidden behind a partition, placed the tray containing the two toys onto the table approximately 61 cm from the infant and 91 cm from the experimenter, such that the toys were out of both the experimenter's and the infant's reach. In the unfulfilled reach condition, the experimenter looked at the infant and said ‘Hi!’ Then she turned toward the target, saying ‘Look!’ and reached toward the toy, with her arm outstretched saying ‘Oooh’. The experimenter remained in this position for 5 seconds, looking at the toy while opening and closing her hand in an apparent struggle to attain the toy. In the point condition, the experimenter said ‘Look! Oooh’, while turning to look at and point toward the toy, holding the point gesture for 5 seconds. In both conditions, the gestures were produced ipsilaterally (see Figure 2), addressing the movement confound from Study 1. Following the gesture, the experimenter reached down to her left side, picked up a black piece of foam core, and used it to push the tray from the middle of the table to within the infant's reach.

[7]Thirteen additional infants began the procedure but were not included in the sample due to distress (*n* = 3), procedure error (*n* = 4), or side preference (*n* = 6).

[8]Infants in Study 2 were 44% white, 27% African American, 6%Hispanic, and 23% other.

Author Manuscript

Infants' responses and attention during the modeled action were coded as in Study 1. A second independent coder coded 30% of the babies' choices and the two coders agreed in all cases, Cohen's kappa = 1.

Results

Table 1 summarizes infants' responses. For each infant, we calculated the proportion of trials (excluding mistrials) on which the infant selected the toy that had been the target of the experimenter's action. These scores were then compared to chance (50%). Infants in the unfulfilled reach condition systematically chose the toy that had been the experimenter's goal, mean(SEM) = .66(.05), $t(15) = 3.07$, $p < .01$, $\eta^2 = .39$. In contrast, infants in the point condition chose randomly, mean(SEM) = .42(.05), $t(15) = -1.71$, $p = .11$, $\eta^2 = .16$. Infants in the unfulfilled reach condition were reliably more likely to select the goal toy than were infants in the point condition, $t(30) = 3.44$, $p < .01$, $\eta^2 = .44$.[9]

We next evaluated whether this difference in infants' responses could have derived from differences in the extent to which the two actions directed infants' attention to the targeted toy. In Study 2, both actions were ipsilateral, ruling out the possibility that infants in Study 1 were only imitating contralateral reaches; however, the two gestures were physically different (dynamic versus static), and this could have led to differential effects on infants' attention. As in Study 1, we estimated the extent to which infants' attention was drawn to the targeted toy by calculating the amount of time during which infants looked at the target toy versus the non-target toy. Indeed, infants in the two conditions differed on this measure ($\text{Mean}_{\text{time target minus time non-target}}(\text{SEM})_{\text{unfulfilled}} = 3.98(.25)$, $\text{Mean}_{\text{time target minus time non-target}}(\text{SEM})_{\text{point}} = 2.42(.41)$; $t(26) = 2.995$, $p < .01$, $\eta^2 = .26$), perhaps due to the motion differences between the two conditions. Despite this difference, further analyses indicated that attentional differences between the two conditions are unlikely to account for the differential imitation: The amount of looking to the target toy versus the non-target toy was not reliably correlated with infants' tendency to choose that toy in either condition ($r_{\text{unfulfilled reach}} = -.07$, $p = .81$; $r_{\text{point}} = .31$, $p = .27$). Furthermore, adding attention to the goal toy versus the non-goal toy as a covariate in the comparison of infants' responses on imitation trials in the two conditions yielded a significant condition difference ($F(1, 25) = 7.15$, $p < .05$), and no significant effect of attention to the goal toy ($F(1, 25) = .52$, $p > .47$). These analyses indicate that although differences in attention across conditions existed, they do not account for infants' responses on imitation trials.

Including movement in the reaching condition provided an ecologically rich modeled event (struggling toward the goal). However, this choice had the unintended consequence of more effectively directing infants' attention to the goal toy compared to the point condition. Although follow-up analyses indicated that this difference between the grasp and point conditions was unlikely to account for infants' responses, in Study 3 we endeavored to create a more closely matched, though less ecologically rich, grasping event. In this condition, the experimenter's unfulfilled reach was static and ipsilateral, eliminating the difference in

[9]Imitative patterns in Study 2 were reflected in individual patterns of response. In the unfulfilled reach condition, 11 infants selected the goal toy more than 50% of the time and three selected it less than 50% of the time, sign test $p < .06$. In contrast, in the point condition, four infants selected the goal toy more than 50% of the time and nine selected it less than 50% of the time, sign test $p = .26$.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

motion that was present in Study 2. The imitation results from the static unfulfilled reach condition were compared to the point control from Study 2.

Study 3

Method

Participants—Sixteen full-term 7-month-olds (seven girls and nine boys; mean age = 6;27) participated in the static unfulfilled reach condition.[10],[11]

Procedure—Study 3 was identical to Study 2, except that infants were presented with a static, rather than a dynamic, unfulfilled reach gesture (see Figure 2).

Infants' responses and attention during the modeled action were coded as in Studies 1 and 2. A second independent coder coded 30% of the babies' choices and the two coders agreed in 96% of cases, Cohen's kappa = .72.

Results

Table 1 summarizes infants' responses. Infants in the static unfulfilled reach condition systematically chose the toy that had been the experimenter's goal, mean (SEM) = .67(.05), $t(15) = 3.09$, $p < .01$, $\eta^2 = .40$, and they were reliably more likely to select the goal toy than were infants in the point condition in Study 2, $t(30) = 3.47$, $p < .005$, $\eta^2 = .29$.[12] Responses in the static reach condition did not differ from those in the dynamic reach condition in Study 2, $t(30) = -.066$, $p = .95$. Importantly, the static reach and the point gesture did not differentially attract the infants' attention to the target versus the non-target ($\text{Mean}_{\text{time target minus time non-target}}(\text{SEM})_{\text{static unfulfilled}} = 2.56(.31)$, $\text{Mean}_{\text{time target minus time non-target}}(\text{SEM})_{\text{point}} = 2.42(.41)$; $t(29) = -.28$ $p = .78$, $\eta^2 = .02$) (see Table 2). Infants' attention to the goal was not reliably correlated with their tendency to choose the targeted toy ($r_{\text{static unfulfilled}} = .16$, $p = .55$), and when attention to the goal toy was entered as a covariate in the analysis comparing responses in the static grasp and point conditions, the condition difference remained significant, $F(1, 29) = 11.34$, $p < .005$, and no reliable effect of attention was found, $F(1, 28) = 1.44$, $p > .24$.

General discussion

Our findings shed light on the development of imitation and on the nature of infants' action representations. They indicate that during the first year of life, infants imitate actions based on an analysis of the agent's goals and that they are able to apply this analysis even when there is no outcome information present, as in the case of an unfulfilled reach. Like older children, 7-month-old infants systematically reproduced the goals of observed actions, both for completed actions and for incomplete reaching actions. The control conditions presented

[10]Infants in Study 3 were 50% white, 19% African American, and 31%other.

[11]Two additional infants began the procedure but were not included in the sample due to more than half of the trials being mistrials (n =1) or side preference ($n = 1$).

[12]Imitative patterns in Study 3 were reflected in individual patterns of response. In the static unfulfilled reach condition, 12 infants selected the goal toy more than 50% of the time and three selected it less than 50% of the time, sign test $p < .05$. In contrast, in the point condition, four infants selected the goal toy more than 50% of the time and nine selected it less than 50% of the time, sign test p = .26.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

infants with similar patterns of motion that directed their attention in similar ways to the target objects, but did not elicit the same responses from infants. These controls support the conclusion that infants' responses were driven by their analysis of a particular goal-directed action, grasping, rather than to lower-level properties of the modeled actions.

Previous research has documented imitation of bodily movements in newborn infants (Meltzoff & Moore, 1977; Meltzoff, 2004) and imitation of actions on objects by 6 to 9 months (Collie & Hayne, 1999; Meltzoff, 1988). By the second year of life, imitation reflects a more abstract analysis of others' intentions, with infants showing evidence of imitating the inferred goals of failed attempts (Meltzoff, 1995), imitating goals at multiple levels of abstraction (Carpenter *et al.*, 2005; see also Bekkering *et al.*, 2000), and using imitation as a possible means to discover the purpose behind ambiguous actions (Gergely *et al.*, 2002). Our findings shed light on developments between these two time periods. By 7 months, infants selectively reproduce the goals of observed actions. This finding indicates that imitative behavior comes to reflect emerging abilities to analyze action as goal directed during the first year.

We do not yet know the limits of 7-month-olds' ability to infer the goals of incomplete actions. The events in Studies 2 and 3 were familiar and simple, and thus easier to analyze and reproduce than the novel actions and means–end sequences that have been used in research with older children. Nevertheless, in selectively reproducing the actor's apparent goal, infants read beyond the actor's physical motions to the goal that might have been realized had her action been completed. This finding suggests that although younger infants may require more support to infer the goals of incomplete actions than do older children, they may not be qualitatively different from older children in their abilities to analyze goal-directed actions.

Given that looking time findings sometimes yield a different picture of infant cognition than do more active measures, it is noteworthy that the current results converge with those of habituation studies. One possible reason for this is that the representations that contribute to infants' action understanding may be closely linked to both motor abilities and perceptual abilities. Recent work in adult humans and non-human primates has shown that action perception and action production draw on common neural and cognitive representations (Rizzolatti, Fadiga, Gallese & Fogassi, 1996; Blakemore & Decety, 2001; Decety & Sommerville, 2003; Hommel, Muessler, Aschersleben & Prinz, 2001; Meltzoff, 2007). It has been proposed that these ‘mirror’ representations exist early in life and play a role in development (Meltzoff & Decety, 2003; Woodward, 2005). Consistent with this proposal, recent experiments have documented relations between infants' ability to produce well-organized goal-directed actions and their comprehension of others' actions as goal-directed. These two abilities are correlated in development (Brune & Woodward, 2007; Sommerville & Woodward, 2005; Woodward & Guajardo, 2002), and interventions that alter infants' action production affect their subsequent perception of others' actions (Sommerville *et al.*, 2005). These studies, combined with the current findings, suggest that even younger infants, with the ability to reach, might also imitate the goals of others' reaches. In addition, presumably older, pointing infants should imitate the target of a point gesture. Further study should be carried out to test these hypotheses.

The extent to which infants' responses were guided by mirror systems is an important open question. This question aside, the current findings demonstrate the representation and reproduction of action goals at 7 months of age. These findings therefore enrich the evidence for goal representation in young infants and indicate that this aspect of action perception structures infants' own actions from early in life.

Acknowledgments

This research was supported by NSF grant number 0446706 to the third author and a Richter Undergraduate Research grant from the University of Chicago to the first author. We thank Neha Mahajan, Rebecca DeNale, Justin Stankiewicz, Sigrid Luhr, Jennifer Buresh, and Joel Tan for their assistance in conducting the studies, and Paul Bloom and others at Yale for their comments on an earlier version of the manuscript. We are grateful to the parents and infants who participated in the studies. JKH is now at Yale University. EVH is now at Queen's University. ALW is now at the University of Maryland, College Park.

References

Aronson S. Ingest (Version 1.7). 1999

Baldwin DA, Baird JA. Discerning intentions in dynamic human action. Trends in Cognitive Sciences. 2001; 5(4):171–178. [PubMed: 11287271]

Behne T, Carpenter M, Call J, Tomasello M. Unwilling versus unable: infants' understanding of intentional action. Developmental Psychology. 2005; 41(2):328–337. [PubMed: 15769189]

Bekkering H, Wohlschlager A, Gattis M. Imitation of gestures in children is goal-directed. Quarterly Journal of Experimental Psychology. 2000; 53A:153–164.

Bellagamba F, Tomasello M. Re-enacting intended acts: comparing 12- and 18-month-olds. Infant Behavior and Development. 1999; 22(2):277–282.

Blakemore SJ, Decety J. From the perception of action to the understanding of intention. Nature Reviews Neuroscience. 2001; 2:561–567. [PubMed: 11483999]

Brune CW, Woodward AL. Social cognition and social responsiveness in 10-month-old infants. Journal of Cognition and Development. 2007; 2(8):3–27.

Carpenter M, Akhtar N, Tomasello M. Fourteen-month-olds differentially imitate intentional and unintentional actions. Infant Behavior and Development. 1998; 21(2):315–330.

Carpenter M, Call J, Tomasello M. Twelve- and 18-month-olds copy actions in terms of goals. Developmental Science. 2005; 8(1):F13–F20. [PubMed: 15647059]

Collie R, Hayne H. Deferred imitation by 6- and 9-month-old infants: more evidence for declarative memory. Developmental Psychobiology. 1999; 35(2):83–90. [PubMed: 10461122]

Csibra G, Gergely G, Biro S, Koos O, Brockbank M. Goal attribution without agency cues: the perception of 'pure reason' in infancy. Cognition. 1999; 72(3):237–267. [PubMed: 10519924]

Decety J, Sommerville JA. Shared representations between self and other: a social cognitive neuroscience view. Trends in Cognitive Sciences. 2003; 7(12):527–533. [PubMed: 14643368]

Gergely G, Bekkering H, Kiraly I. Rational imitation in preverbal infants. Nature. 2002; 415:755.

Gergely G, Csibra G. Teleological reasoning in infancy: the naive theory of rational action. Trends in Cognitive Sciences. 2003; 7(7):287–292. [PubMed: 12860186]

Guajardo JJ, Woodward AL. Is agency skin deep? Surface attributes influence infants' sensitivity to goal-directed action. Infancy. 2004; 6(3):361–384.

Hommel B, Musseler J, Aschersleben G, Prinz W. The theory of event coding (TEC): a framework for perception and action planning. Behavioral and Brain Sciences. 2001; 24:849–937. [PubMed: 12239891]

Johnson SC. The recognition of mentalistic agents in infancy. Trends in Cognitive Sciences. 2000; 4(1):22–28. [PubMed: 10637619]

Johnson SC, Booth A, O'Hearn K. Inferring the goals of a nonhuman agent. Cognitive Development. 2001; 16(1):637–656.

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Author Manuscript

Jovanovic, B., Kiraly, I., Elsner, B., Aschersleben, G., Gergely, G., Prinz, W. Action effects enhance the perception of action goals. Presentation at the International Society for Infant Studies; Toronto, Canada: 2002.

Kiraly I, Jovanovic B, Prinz W, Aschersleben G, Gergely G. The early origins of goal attribution in infancy. Consciousness and Cognition. 2003; 12:752–769. [PubMed: 14656515]

Luo Y, Baillargeon R. Can a self-propelled box have a goal? Psychological reasoning in 5-month-old infants. Psychological Science. 2005; 16(8):601–608. [PubMed: 16102062]

Malle, BF.Moses, LJ., Baldwin, DA., editors. Intentions and intentionality: Foundations of social cognition. Cambridge, MA: MIT Press; 2001.

Mangold International. Interact, Version 8. 1998

Meltzoff AN. Infant imitation and memory: nine-month-olds in immediate and deferred tests. Child Development. 1988; 59(1):217–225. [PubMed: 3342714]

Meltzoff AN. Understanding the intentions of others: re-enactment of intended acts by 18-month-old children. Developmental Psychology. 1995; 31(5):838–850. [PubMed: 25147406]

Meltzoff, AN. The case for developmental cognitive science: theories of people and things. In: Bremner, G., Slater, A., editors. Theories of infant development. Malden, MA: Blackwell Publishers; 2004. p. 145-173.

Meltzoff AN. 'Like me': a foundation for social cognition. Developmental Science. 2007; 10(1):126–134. [PubMed: 17181710]

Meltzoff, AN., Decety, J. What imitation tells us about social cognition: a rapproachment between developmental psychology and cognitive neuroscience. In: Frith, C., Wolpert, D., editors. The neuroscience of social interaction: Decoding, imitating, and influencing the actions of others. Oxford: Oxford University Press; 2003. p. 109-130.

Meltzoff AN, Moore AK. Imitation of facial and manual gestures by human neonates. Science. 1977; 198:75–78. [PubMed: 17741897]

Rizzolatti G, Fadiga L, Gallese V, Fogassi L. Premotor cortex and the recognition of motor activities. Cognitive Brain Research. 1996; 3:131–141. [PubMed: 8713554]

Sodian B, Thoermer C. Infants' understanding of looking, pointing, and reaching as cues to goal-directed action. Journal of Cognition and Development. 2004; 5(3):289–316.

Somerville J, Woodward A. Pulling out the intentional structure of action: the relation between action processing and action production in infancy. Cognition. 2005; 95(1):1–30. [PubMed: 15629472]

Sommerville JA, Woodward AL, Needham A. Action experience alters 3-month-old infants' perception of others' actions. Cognition. 2005; 96(1):B1–B11. [PubMed: 15833301]

Tomasello M, Carpenter M, Call J, Behne T, Moll H. Understanding and sharing intentions: the origins of cultural cognition. Behavioral and Brain Sciences. 2005; 28:675–735. [PubMed: 16262930]

von Hofsten C, Siddiqui A. Using the mother's actions as a reference for object exploration in 6- and 12-month-old infants. British Journal of Developmental Psychology. 1993; 11(1):61–74.

Woodward A. Infants selectively encode the goal of an actor's reach. Cognition. 1998; 69:1–34. [PubMed: 9871370]

Woodward A. Infants' ability to distinguish between purposeful and non-purposeful behaviors. Infant Behavior and Development. 1999; 22(2):145–160.

Woodward, A. The infant origins of intentional understanding. In: Kail, RV., editor. Advances in child development and behavior. New York: Academic Press; 2005. p. 229-262.

Woodward A, Guajardo J. Infants' understanding of the point gesture as an object-directed action. Cognitive Development. 2002; 17(1):1061–1084.

Zelazo, PD.Astington, JW., Olson, DR., editors. Developing theories of intention: Social understanding and self-control. Mahwah, NJ: Lawrence Erlbaum Associates; 1999.

Figure 1. Pictures illustrating the two reach types used in Study 1: Grasp, and Back of Hand

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

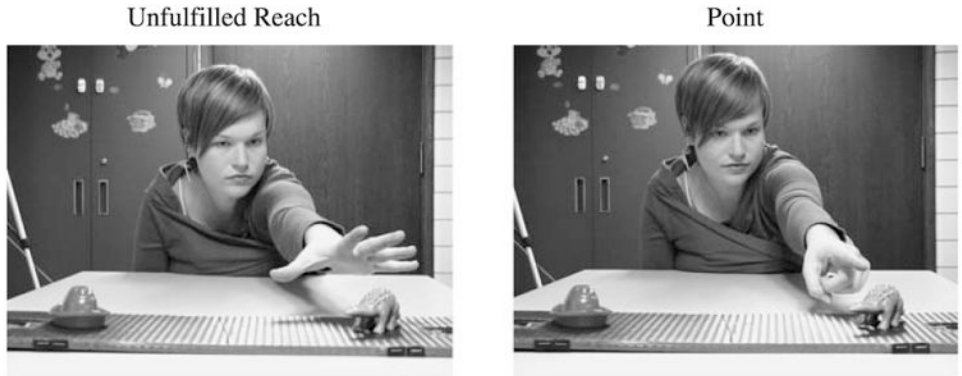

Figure 2. Pictures illustrating the two reach types used in Studies 2 and 3: Unfulfilled Reach, and Point

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Author Manuscript Author Manuscript Author Manuscript Author Manuscript

Table 1

Mean (SEM) number of trials (of 6) on which the infants chose the experimenter's prior goal, chose the experimenter's non-goal, didn't choose, or on which the trial was a mistrial

Condition	Goal choice	Non-goal choice	No choice	Mistrial
Grasp	3.38 (.31)	2.06 (.34)	.38 (.20)	.19 (.10)
Back of Hand	2.63 (.26)	2.69 (.30)	.44 (.20)	.25 (.11)
Unfulfilled Reach	3.81 (.32)	1.94 (.31)	0 (0)	.25 (.14)
Point	2.44 (.26)	3.38 (.29)	.06 (.06)	.13 (.09)
Static Unfulfilled Reach	3.63 (.33)	1.75 (.23)	.06 (.06)	.56 (.18)

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 2

Mean (SEM) seconds of looking at the goal toy minus the non-goal toy during the modeled action

Study	Condition	Seconds goal minus non-goal
1	Grasp	2.66 (.43)
	Back of Hand	2.67 (.40)
2	Dynamic Reach	3.98* (.25)
	Point	2.42* (.41)
3	Static Reach	2.56 (.31)

*There is a significant difference between these conditions, $p < .01$.