

# Infants' Understanding the Intention and Goal of an Adult's Action with Objects : Why Do They Look at the Adult's Hand?

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## Abstract

Tool use is one of the goal directed actions infants learn efficiently through interacting with adults. This study examines the roles of infants' attention to an adult's hand and joint engagement with an adult in learning tool use, and describes their development in understanding the intention of the adult. In Experiment 1, an experimenter inserted a toy car into an opaque tunnel, then showing how to extract the car by using a hammer. Forty-nine 6-, 10-, 12- and 19-month-olds were then asked to get the car from the tunnel. 19-month-olds could use the hammer as a tool by themselves, while more than 80% "Failure" was recorded with the 6-, 10- and 12-month-olds. In Experiment 2, the opaque tunnel was replaced by a transparent one. Thirty-five 6-, 10-, and 12-month-olds participated. Success in joint engagement was more observable with the transparent tunnel compared to the opaque one in 10- and 12-month-olds. 10-month-olds grasped the goal (the car coming out), connecting it to the actor (or her hand holding the hammer), through joint engagement with the adult. These results indicate that interaction with an adult and making the function of a tool transparent to infants both facilitate infant understanding of adult intention and causality with objects.

**Keywords:** tool use, attention to an adult's hand, joint engagement, causality, goal directed actions

Young children in their second year begin to use various types of tools such as spoons, pens, shovels and ultimately, language. Human infants especially learn tool use efficiently compared to other species. How do they succeed in learning these skills? We approached this question by examining the following two aspects; one is infants' propensity to imitate adults' actions, and the other is the role of adults interacting with the child.

First, imitative learning is considered necessary for children to acquire the conventional use of many cultural artifacts. Tomasello (1999), in his work on the social transmission of tool use in chimpanzees, differentiated between imitative learning and emulation learning; young children pay attention to an actor's behavior or intentions, and successfully imitate the means used, however, primates focus on the salient outcome of an action and reinvent the means through a process of trial and error. Nagell, Oleguin, and Tomasello (1993) compared chimpanzees and 2-year-old children on a tool-use task with two possible methods leading the

same end result. They found that the human children used the tool in the same way as the demonstrator, whereas the chimpanzees ignored the demonstrator's specific method of tool use. Myowa-Yamakoshi and Matsuzawa (1999) also suggested that chimpanzees had difficulty noting details of the demonstrator's body movements performing a manipulation. For humans the goal or intention of the demonstrator is a central part of what they perceive (Tomasello, 1996).

Amano and Kezuka's study results (1996) concur with these findings, as they showed that human infants even in the first year paid attention to an adult's hand during object performance. Infants they observed at the ages of 7, 10 and 12 months reached for an adult's hand and put their hand on it or the object the hand was holding; they tried to do the same things as the adult. Amano and Kezuka interpreted infants' focusing on the adult's hand as a prerequisite step in acquiring tool use. Their research also showed a precursor of joint visual attention; infants' orientation to the adult's hand emerges in the first half of the first year. Infants seemed to recognize hands as agents of change as early as at the ages of 3 and 4 months (Amano, Kezuka, & Yamamoto, 2004).

Other studies have shown that infants in the second half of the first year expect the actions of human hands to be goal directed. Using the habituation paradigm, Woodward (1999) suggested that even 5-month-old infants can begin to construe grasping events as goal directed. In a modified version of Woodward's paradigm, Hofer, Hauf, and Aschersleben (2005) reported that 9-month-old infants did not interpret actions performed by a mechanical device as goal directed, however, showing how a human operated the device prior to the test phase enabled 9-month-old infants to interpret the actions as goal-directed, as well. Saxe, Tenenbaum, and Carey (2005) reported that by the age of 10 months, hands are categorized as an intentional agent; their research showed that 10- and 12-month-old infants expect a human hand to be the primary cause of an inanimate object's motion.

Secondly, and exclusively in human cultural learning, there is the essential role of adults interacting with the child; adults direct children to which aspects of their own actions they should attend. Adults make their children apply specific means (tools) in certain situations, and give approval or encouragement for the children's performances as needed. These well-intentioned demands by adults ensure efficient and successful tool use. However these social factors have received a lesser focus in early cognitive development studies, and infants typically have been observed while exploring and trying to solve a practical problem on their own, without help or any instruction from others (Goubet, M., Rochat, P., Maire-Leblond, C., & Poss, S., 2006).

Tomasello, Carpenter, Call, Behne, and Moll (2005) proposed that the crucial difference between human cognition and that of other species is the ability to participate with others in collaborative activities with shared goals and intentions. They proposed this developmental pathway of infants' understanding and sharing intentions: (1) young infants (3 months) understand other persons as animate agents and share emotions, (2) 9-month-olds understand other persons as goal-directed agents and share goals, (3) 14-month-olds understand other persons as intentional agents and share intentions and engage with them collaboratively.

Typically, in the case of tool using, infants need to adjust their handling to specific

applications, and they are often not able to imitate or produce proper actions by themselves. Adults perform the model of tool use they want children to acquire, and if the children fail, they control them by literally taking their hands and/or feet and guiding them; in other words, they make them participate in joint engagements with adults. This can be viewed as an early phase of collaborative activities between infants and adults.

Meanwhile, converging literature suggests a close link between infants' action production and understanding others' actions (Sommerville & Woodward, 2005; Sommerville, Woodward, & Needham, 2005; Kanakogi & Itakura, 2011, Gerson & Woodward, 2013). Sommerville and Woodward (2005) suggested that this link is in place by at least 10 months of age. Sommerville, Woodward, and Needham (2005) showed that 3-month-old infants' action experience facilitated their perception of others' actions: they focused on the relation between the actor and her goal. Also Kanakogi and Itakura (2011) showed the developmental correspondence between action prediction and motor ability in 4- to 10-month-old infants and adults.

Unlike the actions noted in these studies, joint engagement is not always a voluntary action, but we find that it also might facilitate infants' perception of causality. Tomasello et al. (2005) noted that infants' understanding and sharing intentions is necessary for collaborative engagement. Conversely, however, it might be presumed that infants come to be aware of adults' intentions by sharing action experiences with them.

This study aimed to examine the role of infants' attention to an adult's hand (or action), the role of adults' instruction, especially joint engagement with the adult on acquiring tool use, and what developmental changes in infants' understanding an adult's intentions took place during this process. We designed the experiments in a social context familiar in daily life.

## Experiment 1

Our first experiment was carried out with a wide range of ages; 6- to 19-month-olds, to examine the process of acquiring tool use, including the preliminary steps toward it, and to clarify (1) the role of infants' attention to the adult's hand, (2) the role of joint engagement with adults, and (3) the developmental process in infants' understanding the intention of an adult's action.

### Method

*Participants.* Forty-nine infants participated and were divided into four age groups: sixteen 6-month-olds ( $M=7.1$ , range=6.7-7.6), fifteen 10-month-olds ( $M=9.9$ , range=9.4-10.2), ten 12-month-olds ( $M=12.2$ , range=11.7-12.6), and eight 19-month-olds ( $M=19.4$ , range=19.0-19.9). An additional three infants were excluded because of fussiness. All infants were recruited from babies who attended a regular health check-up at a local government-funded Health Center in Gunma, Japan.

*Setting and Materials.* Infants were observed in a partitioned-off area of the health center. Four video cameras were set up for recording. The first camera focused on the infant's face. The second focused on the face of experimenter, the third shot from the infant's right side, and the fourth recoded from the infant's left side.

The materials were a miniature toy car, an opaque cardboard tunnel (4 cm in diameter, 15

cm in length) and a bamboo hammer (T-shaped with a 5 cm long handle). The color of all the materials was red. The hammer was used as a tool to push the car through the tunnel, which had been firmly fixed on the table. To push the car into and through the tunnel, the hammer was laid down and operated horizontally, not conventionally, and thus in a way new to the infants.

*Procedure.* The infants were seated on their mothers' laps and engaged in a face-to-face interaction with the experimenter. The experimenter put the toy car into the tunnel, and then she showed how to get the car from the tunnel by using the hammer to push the car out of the tunnel. She used her left hand to handle the hammer because most infants have right hand preference, and we expected that using her left hand would facilitate coordinated joint engagement in the face to face situations with the infants. During the demonstration phase, she talked to the infants, explaining each scene; "Look! The car is going into the tunnel!" and, "It's gone!"... "You can get it by doing this," (showing the hammer). "I'll show you... Watch this!"... "Look, it's coming...Here it is!"

She repeated the demonstration twice, then put the car into the tunnel and asked the infants to get the car from the tunnel. When the infants could not succeed, she tried to help them in coordinated joint engagement. These trial sessions were repeated until the infants succeeded or would not try anymore (not pay their attention to the trial). A single trial period ran from putting the car in the tunnel to pushing the car out of it. The total number of trials completed depended upon the individual infants.

*Coding.* The pictures taken by the four cameras were integrated into a single videotape recorder and analyzed frame by frame (1 frame=1/30 sec). Infants' behavior during the sessions (including the two demonstration sessions) was coded from the videotape.

Each of the infant's trials (working level with the hammer, tool using level) were categorized as follows :

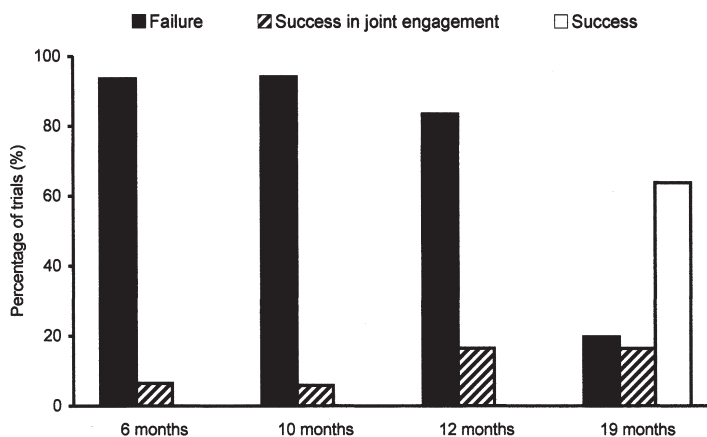
- Failure: the infants looked at the adult's face and/or hand, or they tried to manipulate the hammer or the tunnel, but failed to get the car. The experimenter pushed the car through the tunnel.
- Success in joint engagement: the infants were not able to push the hammer through the tunnel to get the car by themselves, and were helped by the adult; then they pushed it together with the adult in joint engagement. In the case of older infants, when inserting the hammer into the tunnel, they found it difficult to adjust the orientation of the two objects, and they needed help; this intervention was also included under "joint engagement."
- Success: the infants were able to push the hammer through the tunnel to get the car by themselves.

Each of the infant's looking and/or touching (including reaching, grasping, picking up, and manipulating) responses to the experimenter's face, hands and the objects (or objects in hand) were combined and coded as indexes of their attention. Four stages were chosen from the sequence of events during each trial (see Table 1), and the presence/absence of their attention responses were coded in each stage of a trial. We analyzed the frequency of infants' attention responses based on total numbers of the same tool using level trials of each age group. Not taking differences among individuals into consideration, we focused the differences among each

trial's level of tool use. A random sample of 20% of the infants was coded by a second coder. Cohen's kappa coefficient was  $\kappa = .73$  for "Face,"  $.80$  for "Hand,"  $.96$  for "Hammer,"  $.77$  for "Hand (Hammer),"  $.78$  for "Tunnel,"  $.89$  for "Hand (Car)," and  $.76$  for "Car." The main coder's data was used for analyses.

## Results & Discussion

*Infants' tool using level.* Figure 1 shows the percentage of trials as failure, success in joint engagement, and success at each age group. A significant difference was found between 19-month-olds and the younger three age groups ( $\chi^2(3) = 60.20, p < .0001$ ; except "success" category); "success" first appeared in the 19-month-olds. More than 80% "Failure" was recorded with the younger three age groups; 6, 10 and 12-month-olds. A significant difference was also found among the younger three age groups ( $\chi^2(2) = 12.06, p < .0024$ ). "Success in joint engagement" was more observable in the 12-month-olds (Tukey test for pairwise comparison,  $p < .05$ ).



**Figure 1** Tool using level in Experiment 1 (Opaque tunnel) : Percentage of trials categorized as failure, success in joint engagement, and success; at 6 months (number of total trials=154), 10 months (n=188), 12 months (n=121) and 19 months (n=122).

*Infants' attention responses to the person, the person (object)<sup>1</sup>, and the objects.* Table 1 shows infants' responses in four stages from the sequence of events during each trial. The percentage means the total appearance ratio calculated based on the total trials of each tool using level in each age group. For each age group, in the different tool using levels, which aspect the infants paid attention to was compared by performing a Fisher's exact test. The shaded regions in Table 1 show that significant differences ( $p < .05$ ) were found between "Failure" and "Success in joint engagement" of the 12-month-olds, and between "Failure" and "Success" at the 19-month-olds. As compared to "Failure" trials, the 12-month-olds paid less

1 The "person (object)" stands for the conditions in which the experimenter was either holding or pointing to one of the objects. In this case, we cannot determine which infant attention are directing to, the person or the object.

attention to “Hand” but more attention to “Hammer” at the first stage in “Success in joint engagement” trials. In the second stage, they attended more to “Hand (*Hammer*),” and in the fourth stage, their attention to “Tunnel” and “Hand (*Hammer*)” was greater. The 19-month-olds paid less attention to “Face” and “Tunnel (+ *Car*),” but more attention to “Hammer” at the first stage in “Success” trials. In the second stage, they attended to “Tunnel (+ *Car* + *Hammer*)” more in order to insert the hammer into it. In the fourth stage, they attended to “Hand (*Hammer*)” to pull the hammer out from the tunnel.

For “Failure” trials, the infants’ attention responses in the different age groups, except the 19-month-olds, were compared by performing an exact test. The following significant age group differences were found ( $p < .05$ ). The 6-month-olds paid less attention to “Hammer” at the first stage than other two groups did. They looked at “Face” more in the second stage and paid attention to Tunnel (*Hammer*) more in the third stage. The 10-month-olds paid less attention to “Hand” at the first stage, and to “Tunnel (+ *Car* + *Hammer*)” at the second stage. At the third stage, they paid less attention to “Hand (*Hammer*).” Their percentage of “Hand (*Car*) ” was less, but of “*Car*” was higher. The 12-month-olds paid more attention to “Hand (*Hammer*) ” at the second stage, and to “Hand (*Hammer*)” and “Tunnel” at the fourth stage, than the other two age groups.

In summary: regardless of the level of tool use, the 6-month-olds compared to the other age groups looked at the experimenter’s face in almost all stages, but especially while the adult was acting with the objects. They hardly seemed to notice the car. The 10-month-olds noticed the car coming out of the tunnel but they did not return to the hand (hammer)/means after that. This may be evidence that they could not understand the goal of the action, but that when something new happened in their environment it seemed to attract them. In an imitation paradigm, Carpenter, Call, and Tomasello (2005) pointed out that the results of an action in an environment are especially salient, and so imitators focus first there, and only under certain conditions do they analyze “backward” to means and sub-goals aimed at that external result. These observations seem to apply to the 10-month-olds in this experiment.

The 12-month-olds, in contrast, shifted their attention to the hand holding the hammer and the tunnel after they noticed the car coming out. Especially in “Success in joint engagement” trials, the 12-month-olds attended more to “Hand (*Hammer*)” when the car was pushing, “Tunnel” and “Hand (*Hammer*)” after they recognized the car, and “Hammer” when they were asked to get the car. These results suggest that the 12-month-olds began to understand a causal relation between hammer (tool), tunnel and car (target); they were noticing the goal (the car coming out) and beginning to connect the means (the hammer pushing) to it through their joint engagements. Finally, the 19-month-olds used the hammer to get the car by themselves; seven eighths of them could insert the hammer into the tunnel and push out the car, then put the car into the tunnel themselves and push it out again. They enjoyed this sequence of actions repeatedly for more than ten minutes. One of the 19-month-olds, however, adhered only to the conventional use of a hammer; he struck the tunnel with the hammer and failed to learn its new usage.

As the opaque tunnel hid the hammer pushing the car from the infants’ sight, it was a difficult challenge for infants still in their first year to figure out the function of the hammer

**Table 1** Infants' attention responses in case of opaque tunnel (%) Hammer = tool Car = target

Age (months)	1st stage		2nd stage		3rd stage		4th stage	
	While the car was in the tunnel		While the car was pushed by the hammer		After the car was pushed out of the tunnel		After infants noticed the car	
	Person	Object	Person	Object	Person	Object	Person	Object
	Face	Hand	Face	Hand	Face	Hand	Face	Hand
	48.6	41.7	69.4	30.6	12.5	32.6	23.6	11.1
	50.0	40.0	70.0	40.0	10.0	30.0	30.0	0.0
	49.7	13.6	76.8	16.4	8.5	16.4	20.3	14.7
	36.4	0.0	90.9	9.1	0.0	36.4	18.2	9.1
	56.4	31.7	86.1	10.9	5.9	29.7	19.8	29.7
	60.0	5.0	95.0	0.0	0.0	60.0	10.0	55.0
	70.8	0.0	95.8	20.8	4.2	8.3	12.5	50.0
	35.0	0.0	75.0	10.0	0.0	10.0	30.0	70.0
	20.5	1.3	43.6	0.0	5.1	25.6	28.2	82.1
	48.6	41.7	69.4	30.6	12.5	32.6	23.6	11.1
	50.0	40.0	70.0	40.0	10.0	30.0	30.0	0.0
	49.7	13.6	76.8	16.4	8.5	16.4	20.3	14.7
	36.4	0.0	90.9	9.1	0.0	36.4	18.2	9.1
	56.4	31.7	86.1	10.9	5.9	29.7	19.8	29.7
	60.0	5.0	95.0	0.0	0.0	60.0	10.0	55.0
	70.8	0.0	95.8	20.8	4.2	8.3	12.5	50.0
	35.0	0.0	75.0	10.0	0.0	10.0	30.0	70.0
	20.5	1.3	43.6	0.0	5.1	25.6	28.2	82.1

Note. JE=joint engagement. The shaded regions indicate that the significant differences were found between "Failure" and "Success in JE" at 12 months, and between "Failure" and "Success" at 19 months (Fisher's exact test,  $p < .05$ ). No significant difference was found at 6 and 10 months.

as a tool. It was clear that the younger infants could not understand the goal of the adult's action. The older infants (12 and 19-month-olds) who were capable of imagining that the car was inside the opaque tunnel, noticed the means and/or the outcome. But the younger infants who did not imagine the inside of the tunnel could not notice the causal relation between the means and/or the outcome, and tried to search for the experimenter's intention ("what is she asking me to do?") throughout the trials, looking at her face, and her (now empty) hand.

## Experiment 2

In an adjustment to make the function of the hammer (tool) more comprehensible to infants younger than 12 months, we substituted a transparent tunnel for the red opaque tunnel in Experiment 2. We expected this modification of the previous experiment to help the infants notice the means and the goal of the process more readily than in Experiment 1.

### Method

*Participants.* Another 35 infants were recruited from the same Health Center as in Experiment 1. All infants were divided into three age groups: thirteen 6-month-olds ( $M=6.9$ , range=6.5- 7.2), thirteen 10-month-olds ( $M=10.0$ , range=9.4-10.5), and nine 12-month-olds ( $M=12.5$ , range=11.3-12.5). No infants were dropped from this experiment.

*Setting and Materials.* The setting and materials were the same as in Experiment 1 except for the tunnel. We used a transparent tunnel instead of a red opaque tunnel.

*Procedure.* The procedure was exactly the same as in Experiment 1.

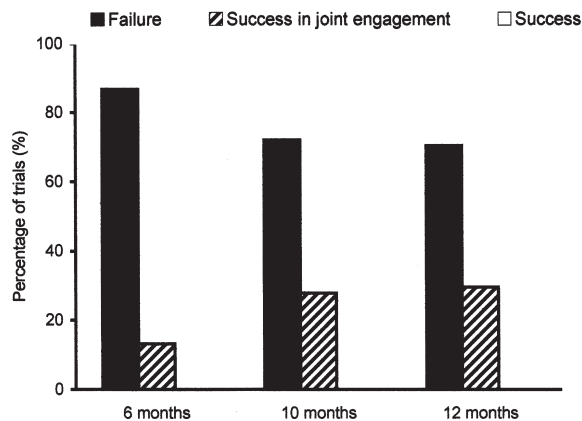
*Coding.* The coding of infants' responses and the assessment of the trials was done in the same way as in Experiment 1. A random sample of 20% of the infants was coded by a second coder. Cohen's kappa coefficient was  $\kappa=.85$  for "Face," .88 for "Hand," .81 for "Hammer," .79 for "Hand (Hammer)," .81 for "Tunnel," for .78 "Hand (Car)" and for .91 "Car." The main coder's data was used for analyses.

### Results & Discussion

*Infants' tool using level.* Figure 2 shows the percentage of trials as failure, success in joint engagement, and success, in each age group. Significant difference was found between the three age groups with tool using level ( $\chi^2(2)=13.04$ ,  $p=.0015$ ). "Success in joint engagement" was more observable in the 10-month-olds and the 12-month-olds (Tukey test for pairwise comparison,  $p<.05$ ).

*Infants' attention responses to the person, the person (object), and the objects.* Table 2 shows infants' responses in the four sequential stages during each trial. The percentage means the total appearance ratio calculated based on the total sessions of each age group and each tool using level. For each age group, the infants' responses in the different tool using levels were compared by performing a Fisher's exact test. The shaded regions in Table 2 show that significant differences ( $p<.05$ ) were found between "Failure" and "Success in joint engagement." In the first stage, the 10-month-olds paid significantly more attention to "Hammer" and "Tunnel (+Car)" in "Success in joint engagement" trials as compared to "Failure" trials. In the second stage, the attention to "Hand (Hammer)" appeared higher in all three age groups. In the third stage, the 10- and 12-month-olds attended to "Hand (Hammer)"





**Figure 2** Tool using level in Experiment 2 (Transparent tunnel) : Percentage of trials categorized as failure, success in joint engagement, and success; at 6 months (total trials=151), 10 months (n=136), and 12 months (n=125).

more. In the fourth stage, the 10-month-olds' attention to "Face" was more observable, and the 12-month-olds' attention to "Hand (*Hammer*)" was higher in "Success in joint engagement" trials.

For "Failure" trials, the infants' attention responses in the different age groups were compared by performing Fisher's exact test. The following significant age group differences were found ( $p < .05$ ), especially between the 6-month-olds and other age groups. The 6-month-olds' looking at "Face" was more observable at the first, second and third stage compared to other two age groups. In the third stage, they paid less attention to "Car" and more attention to "Hand (*Hammer*)" and "Tunnel (+*Hammer*)," and then their responses of "Hand (*Car*)" were observed more. In the fourth stage, their attention to "Hand (*Hammer*)" was lower than that of the 10-month-olds. Regarding "Hand (*Hammer*)" in the second stage, there were significant differences between the three age groups; the percentage of "Hand (*Hammer*)" increased with age. Also, the 12-month-olds' percentage of "Tunnel" in the fourth stage was higher than those of the 10-month-olds.

These results suggest that the 6-month-olds began to recognize the actor as an agent who caused the movement of objects (the car and the hammer); they related the agent (person) to the objects, but it appears that they did not notice either the means or the goal in this situation, because most did not notice the car coming out of the tunnel, and their gaze, instead, remained on the tip of the hammer inside the tunnel. One 6-month-old infant noticed the hammer moving into the tunnel from the right side, and he shifted his gaze to the right, then found the experimenter's hand holding the hammer. When her hand movement stopped, his gaze moved to the hammer contacting the hand and finally he found the car contacting the tip of the hammer. In general though, these youngest infants tended to pay attention to the moving objects (the car or the hammer or the hand), and they also attended to the experimenter's empty hand after it had released the objects.

**Table 2** Infants' attention responses in case of transparent tunnel (%) Hammer = tool Car = target

Age (months)	1st stage			2nd stage			3rd stage			4th stage		
	While the car was in the tunnel			While the car was pushed by the hammer			After the car was pushed out of the tunnel			After infants noticed the car		
	Person	Object	Person (Object)	Person	Object	Person (Object)	Person	Object	Person (Object)	Person	Object	Person (Object)
6	Face	Hammer	Tunnel (+Car)	Face	Tunnel (+Car+Hammer)	Face (Hammer)	Face	Car	Face (Hammer)	Face	Tunnel (+Hammer)	Face (Hammer)
	Hand	3.8	16.8	32.1	59.5	67.2	21.4	30.5	16.0	58.8	46.6	22.1
10	Face	44.3	90.8	32.1	59.5	67.2	21.4	30.5	16.0	58.8	46.6	22.1
	Hand	35.0	25.0	25.0	100.0	75.0	25.0	50.0	15.0	45.0	60.0	35.0
12	Face	30.6	96.9	16.3	74.5	54.1	3.1	12.2	5.1	87.8	26.5	31.6
	Hand	36.8	2.6	57.9	100.0	52.6	0.0	60.5	5.3	92.1	10.5	55.3
Success in JE (n=37)	Face	29.5	97.7	6.8	87.5	59.1	3.4	15.9	10.2	84.1	21.6	22.7
	Hand	32.4	0.0	29.7	100.0	59.5	8.1	56.8	10.8	81.1	24.3	16.2

Note. JE = joint engagement. The shaded regions indicate that the significant differences were found between "Failure" and "Success in JE" (Fisher's exact test,  $p < .05$ ).

The 10-month-olds began to notice the adult's goal-directed action; relating between the hammer (tool) and car (target); noticing the goal (the car coming out) and beginning to notice the means (the hammer pushing) through their joint engagements. One 10-month-old infant grasped the other side of the tunnel as soon as he saw the experimenter inserting the hammer into the tunnel. Similarly, other 10-month-old infants often grasped or looked into the other side of the tunnel. This anticipation was rarely observed in the 6-month-old infants. It was not necessarily the case that temporal order anticipation was not observable in the youngest age group, however, their anticipation did not involve the relevant causal order. For example, when watching the car put into the tunnel, one infant shifted his gaze to the other side of the tunnel, but without noticing the role of the hammer.

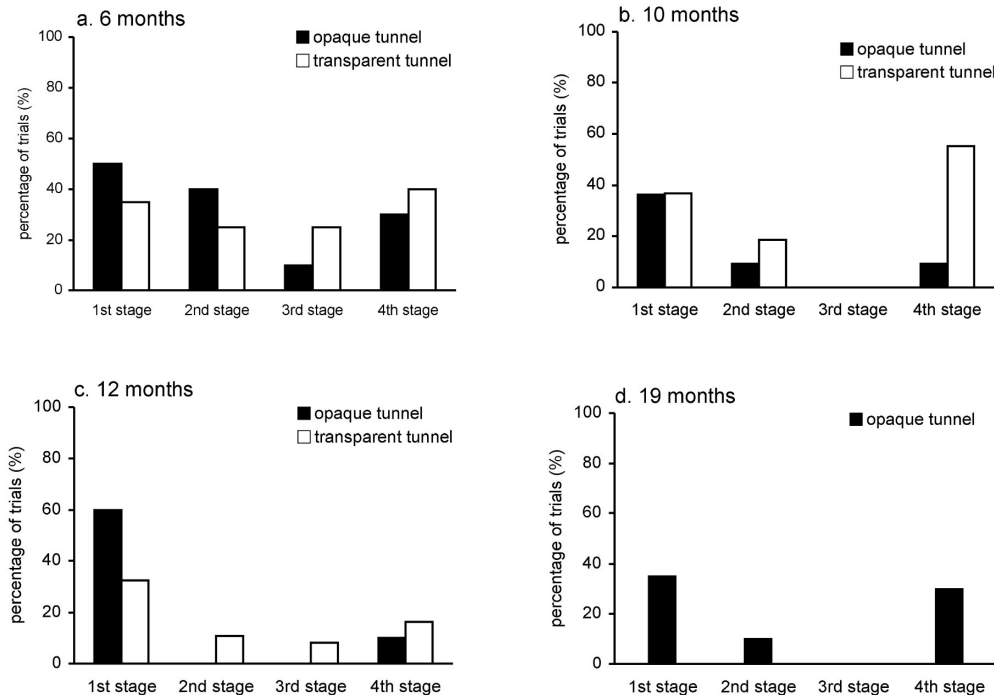
There was no difference between the tool use level of the 10-month-olds and the 12-month-olds, but there was a slight difference in their cognition of causality. After noticing the goal (the car coming out), the 10-month-olds looked at the adult's face and directed their attention to "Person," whereas the 12-month-olds directed their attention to "Object", especially the tunnel. The 12-month-olds' behavior seemed to be inconsistent; they apparently noticed the goal and means because they looked back to the hand (hammer) after they recognized the car coming, but their attention remained more on the car inside the tunnel rather than on the hammer when they were asked to take the car out of the tunnel; they then put their fingers into the tunnel and tried to get the car. The 12-month-olds seemed to recognize the tunnel as an obstacle to getting the car. Putting their fingers into the tunnel may be interpreted as their own action plan to get the car, which seemed to be much easier for them than using the hammer. It suggests that infants will use their body as a tool before they are able to use objects as a tool.

*Experiment 1 versus Experiment 2: Opaque tunnel versus transparent tunnel.* We compared the results of Experiment 2 (transparent tunnel) with those of Experiment 1 (opaque tunnel in an otherwise identical experimental situation). Significant differences in tool use level were found in the 10-month-olds (Fisher's exact test,  $p < .0001$ ) and 12 month olds (Fisher's exact test,  $p = .0162$ ) (see Figure 1 and Figure 2). "Failure" was significantly decreased and "Success in joint engagement" was more observable with the transparent tunnel compared to the opaque tunnel in both age groups.

For "Success in joint engagement" trials of each age group, the infants' attention behaviors at each stage were compared for both types of tunnels using a Fisher's exact test (See Table 1 and Table 2). In the first stage, no significant difference was found between the opaque tunnel and the transparent tunnel experiments in all age groups. In the second stage, the 10-month-olds' attention to "Tunnel (+Car+Hammer)" was more observable with the transparent tunnel ( $p < .05$ ). In the third stage, the 6-month-olds' attention to "Tunnel (+Car+Hammer)" ( $p < .05$ ), the 10-month-olds' attention to "Car" ( $p < .01$ ), and the 12-month-olds' attention to "Tunnel (+Car+Hammer)" ( $p < .01$ ) and "Car" ( $p < .05$ ) were more observable with the transparent tunnel. Also, with the transparent tunnel, the percentage of "Hand (Car)" decreased in all age groups ( $p < .05$ ). In the fourth stage, 10-month-olds' attention to "Face" and "Hand (Hammer)" was more apparent with the transparent tunnel ( $p < .05$ ). In short, in the case of the transparent tunnel, the infants actually witnessed the hammer pushing the car (the means) and they could easily notice the goal (the car coming out) and connect it to the

actor. The 6-month-olds' attention to "Tunnel (+ Car + Hammer)," however, indicates that they seem to be slower to notice the hammer moving in the tunnel, compared to the 10-month-olds.

A different pattern was found for each age group for the looking at "Face" responses (see Figure 3). The 6-month-olds looked relatively often at "Face" in all stages, and they were sensitive to the experimenter's voice in both tunnel experiments. They were especially attentive to the experimenter's face while she was showing them the objects. In the 10-month-olds, a difference was found; the percentage of those looking at 'Face' in the opaque tunnel experiment was the highest in the first stage, whereas the percentage of those looking at 'Face' in the case of the transparent tunnel was the highest in the fourth stage. In the 12-month-olds, the percentages for both tunnels were the highest in the first stage. For the 19-month-olds, the percentages looking at "Face" in the opaque tunnel were the highest in the first and the last stages. These results suggest that the looking behavior at the adult's "Face" in the first stage indicates the infants' referencing to the experimenter's communicative intention ("What did you ask me to do?" ... "What should I do?"), and that of the last stage indicates their confirming the result of the action ("We/You did that?" ... "Look, I did it!"). Similarly, the 10-month-olds' high percentage at the last stage in the transparent tunnel indicates that this experimental situation facilitated infants' understanding the experimenter's intention, because they seemed



**Figure 3** Percentage of trials in which infants looking at the experimenter's face were observed. 1st stage: while the car was in the tunnel, 2nd stage: while the car was pushed by the hammer, 3rd stage: after the car was pushed out of the tunnel, and 4th stage: after infants noticed the car.

to be confirming their successful efforts with the experimenter; “I did it!”

Infants' relating objects during each trial were calculated as “Examining behaviors.” We considered these examining behaviors to be evidence of their perception of object-object causality. The average occurrence of examining behaviors was higher in “Success in joint engagement” trials rather than “Failure” trials in the 10-month-olds with the transparent tunnel, and in the 12-month-olds and 19-month-olds with the opaque tunnel (Welch t-test,  $p < .01$ ). The results suggest that the infants realized the causality of objects more efficiently through joint engagement with the adult.

Table 3 shows the total appearance rate of infants' examining behaviors calculated based on the total “Success in joint engagement” trials of each age group. Except for the 12-month-olds and 19-month-olds, the examining behaviors hardly appeared at all in the experiment with the opaque tunnel, whereas even the 6-month-old infants in the experiment with the transparent tunnel showed some examining behaviors. The combining behavior for “*Hammer & Car*” first appeared in the experiment with the transparent tunnel with all age groups. The 10-month-olds showed more tendency to combine “*Tunnel & Hammer*” as well with the transparent tunnel rather than with the opaque one (Fisher's exact test,  $p = .094$ ).

**Table 3** Infants' examining behaviors in “success in joint engagement” trials (%)

Tunnel	Age (months)	While the car was in the tunnel (1st stage)			In other stages (2nd-4th stages)			
		Tunnel (+ <i>Car</i> ) & <i>Hammer</i>		<i>Hammer</i> & <i>Car</i>	Tunnel & <i>Car</i>		Tunnel & <i>Hammer</i>	
		combine	insert	combine	combine	push back	combine	pull out
Opaque	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	10	9.1	0.0	0.0	0.0	0.0	0.0	0.0
	12	25.0	0.0	0.0	30.0	5.0	15.0	20.0
	19	25.0	70.0	0.0	45.0	15.0	5.0	75.0
Transparent	6	0.0	5.0	5.0	0.0	0.0	5.0	0.0
	10	7.9	5.3	18.4	18.4	2.6	28.9	10.5
	12	16.2	0.0	5.4	24.3	5.4	8.1	10.8

*Note.* “Combine (Tunnel & Car)” includes putting the car into the entrance of the tunnel. The shaded regions indicate that the significant differences were found among the three age groups for each tunnel (Opaque: 10, 12, and 19 months. Transparent: 6, 10 and 12 months) (Fisher's exact test,  $p < .05$ )

Regarding the age differences (see the shaded region of the Table 3) in the experiment with the opaque tunnel, the 19-month-olds' examining behaviors of insert (Tunnel+*Car* & *Hammer*) and pull out (Tunnel & *Hammer*) were significantly more observable compared to the other age groups ( $p < .0001$ ). The 19-month-olds appeared to be able to realize the intended connection between the three objects; tunnel, car and hammer, even in the opaque

tunnel. The 12- and 19-month-olds' examining the combined (Tunnel & Car) occurred significantly more ( $p < .05$ ). In the experiment with the transparent tunnel, examining the combined (Tunnel & Car) significantly appeared at the earlier age of the 10- and 12-month-olds ( $p < .05$ ). In the 10-month-olds, examining the combined (Tunnel & Hammer) also occurred significantly more ( $p < .05$ ) than with the other two age groups. However, the 10-month-olds often presented physically irrelevant combining behavior, such as placing the hammer or the car over the tunnel, releasing the hammer in the other side of the tunnel, or pushing the hammer outside the tunnel. It seemed that they did not understand the spatial relation of the tunnel and the hammer, and the tunnel and the car.

### General Discussion

The two experiments with 6- to 19-month-old infants were conducted to examine the role of young infants' attention behavior to the adult's hand and the role of joint engagement on acquiring tool use, and to describe the developmental process in infants' understanding the intention of the adult's action.

*Experiment paradigm to study infant intention understanding.* First, we propose the distinction, which is not always clearly made and discussed, between object-oriented intention in what has been referred to as "goal directed intention" commonly, and person-oriented intention in what Tomasello et al. (2005) called "communicative intention". In our experiment as well as many other intention or imitation studies, the experimenter (a real person) provided the model of the performance, using objects with the infants. This experimental setting inevitably creates a nesting structure of intentions; the experimenter is facing the infants with a particular communicative intention (person-oriented) and she also has a goal directed intention (object-oriented) in her performance in this social context. From this point of view, as in Meltzoff's study (1995), frequently referred in other intention studies, an experimenter's intentions are quite complex. This study showed that 18-month-old children understood the other's intention and accomplished his/her failed half way acts. Meltzoff said that "his actual intent was to give the impression that he was trying to produce the target," i.e. his actual goal directed intention was to try not to complete the act. Therefore the 18-month-old infants who could re-enact his "intended" acts actually failed to notice his actual goal directed intention, and turned out to follow his hidden communicative intention.

In infant development studies in general, an experimenter's communicative intentions are often carefully controlled or eliminated, as in the above intention study, in which Meltzoff writes that the experimenter maintained a friendly demeanor throughout the demonstrations, and did not express joy at the infants successfully performing the act. Even in habituation experiments, however, it is difficult to totally cut off messages of intention (hidden messages to the participants) from invisible experimenters; in the situation of being brought into and being set in a dark experimental room there is a clear message that you should look at a bright screen that has been set there. Another difficulty we have observed is that infants who cannot understand experimenters' intentions often tend to become fussy and drop out of the experiments.

In our study, conversely, the experimenter's communicative intentions were fairly open. The experimenter's intentional action on objects (object-oriented intention) had a hierarchical structure: achieving the goal of getting the car involved several sub-goals and sub-plans; picking up the hammer, inserting it to the tunnel, pushing out the car and picking up the car again. In consequence the adult's communicative intention (person-oriented intention) was also multi-tiered. In each stage, the adult tried to draw the infants' attention to each aspect of her action and encouraged them to participate with her in the action. Even the youngest infants participating in our experiments demonstrated that they were sensitive to the adult's communicative intention and tried to react to her requests. The infants looked into the adult's face and tried to read her communicative intention.

*The role of infants' attention to the adult's hand.* The adult's hand provided the infants with relevant information for social learning of tool use. The hand moving attracted the youngest infants, and gave clues to help them find the causality of agent-object and then object-object. As the opaque tunnel hid the hammer pushing the car (the means) from the infants' sight, they hardly noticed the car coming from the tunnel (the outcome) and their attention remained on the hand that moved. In those instances, the adult's pointing to the car or grasping the car helped the infants to recognize the car. These results indicate that infants' attention to an adult's hand assures the developmental change toward sharing attention and intentions with adults.

Even the youngest infants seemed to understand that hands cause an inanimate object's motion, i.e. they often related a hand and the object that had been handled. Saxe et al. (2005) and Woodward (1999) reported that hands are categorized as an intentional agent. In our experiments, however, the infants looked at the adult's hand, and then looked at her face. This suggests that what the infants categorized as an intentional agent was clearly not the hands alone but the actor herself. The infants seemed to confirm the adult's intentions (person-oriented and object-oriented) that had appeared in the movement of the hand. In the habituation paradigm, only hands without a figure of person are often used as stimuli (Saxe et al.). The intriguing study by Meltzoff (1995), mentioned earlier in this discussion, measured infants' social referencing to the caretaker who was holding the infant from behind, but not to the presenter. Further research especially for young infants including focus on the question, "whose intention do the infants look to for confirmation?" might be interesting as well.

Striano, Vaish, and Benigno (2006) discussed the meaning of infants' face-looks in the social referencing situation using a "visual cliff." They pointed out two kinds of meanings; information seeking and comfort seeking. We definitely assume that both information and comfort are needed for young children to attempt new challenges. Our study results suggest that the infants' face-looks indicated their high concern for the communicative intention of the adult, i. e. intention seeking, which can integrate information and comfort seeking. There was a difference among the age groups when they looked at the adult's face; the youngest group looked at the face throughout almost the entire period of a trial. They seemed not to understand what the adult wanted them to do, and to struggle, searching for her intention. The older infants' looks increased in the last stage of a trial. They seemed to be confirming the result of their own action or their joint engagement with the adult; confirming the goal reached

or sharing the joy of their accomplishments.

*The role of joint engagement with the adult.* More success in joint engagement with the adult was observable with the transparent tunnel, especially in 10-month-olds and in 12-month-olds, compared with the opaque tunnel. Making the function of the hammer (the tool) transparent to the infants facilitated their understanding and/or sharing the adult's intention, and thus increased their joint engagements with the adult. Moreover, through their joint engagements, the infants could assure themselves of the goal (the car coming out) and the means (the hammer pushing), and could understand the causality of objects. The infants themselves initiated joint engagement by looking at the adult's hand or the hammer in her hand, and by touching or holding them. The youngest infants' joint engagement was less intentional initially; they just paid attention to the adult's hand moving, and adjusted their hand to the movement without clearly sharing the goal. Eventually, though, they seemed to notice the goal (the outcome), and then the means. These results indicate that joint engagement as well as paying attention to the adult's hand helps assure the developmental change toward sharing the goal and intention with the adults.

*The developmental process.* Our results suggest three developmental changes in understanding the intentions of an adult's goal-directed action, as follows :

1. Paying attention to the actor's face and hand: Our observations suggest infants' attention to an actor's face indicated their searching for the actor's intentions, and their attention to the hand indicated that they began to recognize the actor as an agent who caused the change of things.
2. Noticing the goal (the car was coming) and the means (the act of using the hammer) to it. Sharing motivation to use the tool enabled the infants to participate in joint engagement, but still without understanding of the role of the tunnel as an obstacle and how to use the hammer.
3. Noticing the goal (the car was coming) and the means (the function of the hammer) to it through their joint engagements. Based on their understanding the role of the tunnel as an obstacle to getting the car, most of the infants tried to apply their own action plan.

In the transparent tunnel, the first developmental stage appeared in the 6-month-olds, the second in the 10-month-olds, and the third in the 12-month-olds. However, in the case of the opaque tunnel, the cause mediating the effect of the adult's action (the pushing of the car by the hammer) inside the tunnel was invisible to the infants, and so noticing this goal was delayed in all the age groups, and concordantly, the awareness of the actor's using the hammer in the 6-month-olds and that of the actor's effect on the car in the 10-month-olds was also delayed. Our results indicate that the 19-month-olds and some of the 12-month-olds with the opaque tunnel could imagine the causality of invisible things and relate the means to the goal. We hypothesize that their concurrent developmental leap in language acquisition may have enabled this dramatic shift. These infants' ability to imagine a part of other's invisible action may concord with Meltzoff's study of 18-month-old children' re-enacting intended acts. While Meltzoff (1995) showed that 18-month-old children understood the other's intention and accomplished his/her failed half way acts, a replication of that study reported that unlike 18-month-old infants, 12-month-old infants do not have the ability to imagine the outcome that



an intentional act might produce if they do not see that outcome produced (Bellagamba & Tomasello, 1999). They need to observe the full intentional act to see it as intentional.

As noted earlier, Tomasello et al. (2005) proposed a three-step developmental pathway of infants' understanding intentional action; understanding animate action (3 months), understanding pursuit of goals (9 months), and understanding choice of plans (14 months). Our findings are consistent in principle with Tomasello's three steps. However, this study differs from the studies Tomasello referred to, in that those were not tool-use type and did not require relating between objects; or only one object was used (Gergaly, Bekkering, & Kiraly, 2002). In the context of our tool use task, the infants needed to understand the function of the tool, in other words, the causal relation among the objects, which made it more challenging to reach Tomasello's third stage. Furthermore, the infants actually had no effective choices but to use the hammer to get the car. Tomasello proposed the distinction between goal and intention; an intention is a plan of action in pursuing a goal, and an intention thus includes both a means (action plan) and goals. In this framework, it is likely that our 12-month-old infants with the transparent tunnel stopped short at sharing the adult's intention; they put their fingers into the tunnel in vain. We believe, however, that this represents their own action plan to pursue the goal, by following the movement of the car with their fingers instead, which would locate them at a preliminary step toward Tomasello's third stage. Acquiring skill at using a hammer by themselves would be the next challenge for infants at this stage. Further research with infants focusing on the ages of twelve to eighteen months may clarify whether joint engagement with adults would also effectively improve the infant's motor skill in using tools as well as the infant's understanding intentions.

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