Learning through practice versus learning by observation in infants

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This research was funded by MATHESIS (European grand No IST-027574)

Abstract

The age at which infants benefit from observing an adult modeling a new object-related action, as opposed to a practice-only condition, was investigated. Eighty-four infants participated in the study. The effect of observational learning was studied (after a 2-minute delay) in two kinds of task: one involved grasping an unstable object; the other involved retrieving an object presented in such a way that direct grasping was not possible. The tasks were designed so that difficulty would be comparable for the five age groups (8-, 10-, 12-, 15-, and 18-month-olds). Modeling hand orientation for grasping was not effective, except for the eight-month-olds but no more than practice alone at that age. Showing the infants how to retrieve an object not directly graspable was more effective than practice as of 15 months, and significantly at 18 months. Thus, learning by observation varies as a function of task and increases during the second year of life when modeling emphasizes the outcome of object-retrieving movement.

Key words: Skill learning, infants, practice, observation, object retrieval

The aim of the research presented here was to study the development of observational learning in the acquisition of new motor skills, as compared with learning through practice only. There have been many studies on immediate and deferred imitation in recent years (Abravanel & DeYong, 1997; Carpenter, Call, & Tomasello, 2005; Gergely, Bekkering, & Kiraly, 2002; Meltzoff, 1988; Meltzoff & Moore, 1994), many of them aimed at investigating the development of social cognition and intention detection. In contrast, infants' learning by observation of a new skill without immediate imitation has received little interest thus far. According to our definition, learning by observation differs from imitation not only in that the individual performs the observed task after some delay (and not straight after the observation), but also in that it concerns a new skill. It is known that learning of a new skill is improved by observing another individual modeling the new task (see Ashford, Davids, & Bennett, 2007's meta-analysis for a review). Most of the evidence comes from work on adults and on children over four years of age, and concerns the acquisition of "ontogenetic" tasks. These studies have shown a significant advantage of modeling use over a practice-only condition for motor learning, with greater effect when the emphasis of modeling was on movement dynamics than when the emphasis was on movement outcome, in adults but not in children. In infants, the role of imitation in acquiring new skills has been studied mainly in the development of speech (in particular via the auditory canal; see Poulson, Nunes, & Warren, 1989, for a review). Existing studies investigating the influence of goal-directed actions as demonstrated by an adult on an infant's behavior in the first two years of life do not concern skills with a strong phylogenetic basis such as reaching and grasping, but often concern imitation of a novel act on an object (see Elsner, 2007, for a review). Therefore, studying the influence of observation in the acquisition of new skills, including reach-to-grasp, without the possibility for immediate imitation, is the goal of our research.

Neural basis for observational learning

The motor-simulation theory proposes that perceiving actions triggers an internal simulation of the movement to be produced, more or less as a function of the novelty of the action for the observer. This internal simulation involves not only action programming but also the generation of a copy of the movement to be reproduced (Jeannerod, 2001). The theory is supported by increasing knowledge about the common neural pathways underlying the observation of an action and its actual execution (Rizzolatti & Craighero, 2004). For instance, it is known that common neural areas are involved when observing others performing movements and executing motor tasks (Iacoboni et al., 1999), the so-called "mirror neuron" system, which mediates action understanding. Motor facilitation has been found in motor evoked potentials of the hands of individuals observing an experimenter grasping an object (Fadiga, Fogassi, Pavesi, & Rizzolatti, 1995). In addition, the cerebellum seems to play a role in procedural learning as well as in observational learning (Petrosini et al., 2003). All these observations support the notion that observing another person performing an action influences the neuro-motor system of the observer, likely through mapping of an observed action onto the representation of the same action. Some researchers have hypothesized that the mirror neuron system, which mediates anticipation of the observed action, could not be operational before an infant can perform the action herself (Falck-Ytter, Gredeback, & von Hofsten, 2006). However, it can be argued that even before the action can be performed, infants may possess coordination patterns that sufficiently approximate the behavior such that the modeling could be useful for acquiring a new skill.

Observational learning of new skills in infancy

Infancy is a time of intensive learning and acquisition of new skills. To learn these new skills, infants can explore and try to solve the task's problem by trial and error - in other words by practice only. A more economic way, however, would be to learn how to carry out the new task by observing someone else successfully performing it. When infants start being able to sit in a chair, they spend a great deal of time looking around them. But, how much do they learn, and at what age do they start to learn by seeing their care-givers reaching, grasping, and manipulating objects? It is likely that both observational learning and practice contribute to increase their motor repertoire. As an example, blind 9- and 12-month-old infants exhibit delays in fine-motor skill acquisition, locomotion, and posture control, probably not only because of a lack of visual feedback from their own actions (Troester & Brambring, 1993).

A few studies have shown some change in the effect of observation on an infant's actions around the first year. One study showed that the observation of a model producing an action had an impact on infants' exploration at 12 months, but not at nine months (Elsner & Aschersleben, 2003). In this study, an understanding of the specific relations between observed actions and effects was shown to be acquired by 15 months. Another study found that 12-month-olds, but not 9-month-olds, learn means-end relations by observation (Provasi, Dubon, & Bloch, 2001). After 18 months of age, it is clear that after having observed an adult using a novel tool to fetch an out-of-reach object, children readily use the same tool (Chen & Siegler, 2000). Some studies have investigated which aspects of goal-directed actions demonstrated by an adult are encoded in the first two years of life. Not all these studies agree, however, on the relative importance of detecting the intention of the modeler, watching the means used to reach a goal, or being emulated by an end-state, in infants' to imitation of a model (e.g. Huang, Heyes, & Charman, 2002; Meltzoff, 1995; Tomasello, Carpenter, Call, Behne, & Moll, 2005). Despite their discrepancies, in all of the above-mentioned studies, children were allowed to imitate the adult without delay, whereas when infants watch their surrounding care-givers dealing with an object, they usually do not have the opportunity to imitate immediately what they observe. Thus, if one wants to find out about how much they do learn in such a way, observational learning studies - with a delay after observation of the model - rather than imitation studies, are required.

Deferred imitation has sometimes been observed in young infants. For instance, 14-month-old infants who observed an adult demonstrating a target act a week prior reproduced this target act significantly more often than 14-month-old infants who did not observe the demonstration (Meltzoff, 1988). Even 9- and 12-month-old infants have been reported to produce an observed target act more often than control subjects (who did not observe it) after 3-min, 1-week and 4-week intervals (Barr, Dowden, & Hayne, 1996; Bauer, Wiebe, Waters, & Bangston, 2001; Heimann & Meltzoff, 1996; Herbert, Gross, & Hayne, 2006; Meltzoff, 1988). However, these studies have focused on acts which already belonged to the infant's repertoire, or on finding a new affordance of an object with a simple action, but not on the learning of new complex skills. When an action is complicated, such as when it involves using a new tool, infants are more likely to forget the model. For instance, 2-year-old children, who have been shown how to use a stick to bring an out-of-reach toy closer to them, fail to use the stick by themselves after a very short interval of a few minutes only (Buchholz, Bushnell, & Yang, 2007).

A further limitation in most of the studies on imitation and observational learning described here, lies in the fact that the targeted act was similar for infants of different ages. If one wants to more precisely compare observational learning in infants of different ages, task difficulty should be matched accordingly to the competencies of each age group. In the study presented here, we tried to overcome this limitation by devising tasks with levels of difficulty appropriate to the different ages of the infants.

The present study

The goal of the present study was thus to compare the benefit of observing another person without immediate imitation with the benefit of practice only in learning two new object-related skills in infants around their first birthday. Handling an object requires both organizing the hand-arm movement for grasping and understanding the objects' affordance for manipulation. For successful grasping, reaching dynamics and hand preparation must be adapted to the object's extrinsic and intrinsic physical characteristics of distance, shape, and size (von Hofsten, 1989). It may happen that the desired object is not directly graspable: when it is inserted inside another one or half-hidden behind an occluder for instance, in which case infants must solve another problem, and sometimes perform a two- or three-step action to retrieve the object. We hypothesized 1) that the impact of observational learning should vary depending on whether the modeling emphasizes the dynamics of the reaching movement, or the outcome of the object-retrieving movement, and 2) that the impact of this emphasis may differ with age. To test these hypotheses, we compared the effect of modeling on the performances of 8- to 18-month-old infants in two different tasks, one simple task involving the reach-to-grasp of an unstable object, and one complex object-retrieval task.

Method

Participants

Eighty four infants participated in this study. There were seventeen 8-month-olds (7 boys and 10 girls), eighteen 10-month-olds (12 boys and 6 girls), seventeen 12-month-olds (10 boys and 7 girls), eighteen 15-month-olds (10 boys and 8 girls), and fourteen 18-month-olds (8 boys and 6 girls). Data from an additional ten infants were not included in the analyses due to crankiness (N=3) or technical problems during recording (N=7). Infants were recruited from the city' s birth records. Parents were then contacted by letter and participated on a voluntary basis. Parental consent was granted before observing the infants, and the experiment was conducted in accordance with the ethical standards specified in the 1964 Declaration of Helsinki.

Stimuli

In order to study the impact of observational learning for grasping and for complex retrieval, we designed two kinds of tasks: (1) A grasping task, common to all age groups, and (2) a retrieval task, specific to each age group.

The grasping task consisted in grasping a small plastic ball placed on a base. This task required the subject to prepare his hand (hand shape and orientation) while reaching in order to grasp the ball without knocking it off its base. The ball was the same for all age groups (4.0 cm in diameter) but we varied the diameter of the base (from 0.8 cm to 2.0 cm; the older the subjects, the smaller the base), to make the task objectively more difficult the older the group. The interest of this set-up was that although the object was visible, its instability was not, so that not decelerating enough and/or not preparing the hand well enough before touching resulted in the object being knocked off its base.

The retrieval task consisted in retrieving an object presented in such a way that its grasping was not obvious and required solving an additional problem. Since we wanted to compare the effect of observational learning at different ages, we had to find tasks which would be above the capacity of infants in all of the age groups by a comparable amount. Thus, the tasks had to be different for each age group, and we tried to devise tasks which would be failed by more than 50% of infants of the targeted age group. For this purpose, the tasks were chosen so that they would be failed at the targeted age and successful in slightly older infants. For instance, it is known that 8-month-old infants fail to make a detour reaching when an object appears behind a transparent barrier (Bruner, 1970; Diamond, 1981). Getting a tube out of its container using bimanual coordination is failed at 10 months of age but successful around 11-12 months (Fagard & Jacquet, 1989). A typical acquisition of 13-14-month-olds consists in retrieving an object placed inside a box whose lid must first be raised (Bruner, 1970; Fagard & Jacquet, 1989).

And turning an object upside-down in order to retrieve something from its interior is not yet perfectly acquired at 18 months of age (Fagard & Marks, 2000). Finally, tool-use has been shown to improve during the second year (Lockman, 2000), thus we devised a tool-use task for the older age group.

Therefore, the object for the 8-month-olds (*detour reaching*) was a rectangular transparent plastic box (8.2 x 5.5 cm, 12.6 cm high), with only the two lateral sides open (see Figure 1). A small toy was placed just behind the front wall of the box: the subject had to resist the tendency to grasp the object seen straight in front of him, and make a detour. The 10-month-olds' object (*tube out of its container*) consisted of a wooden container (2.4 x 2.5 cm, 9.2 cm high) inside which was inserted a plastic tube with a brightly coloured cap, protruding from the container by 2.5 cm. For the 12-month-olds (*toy inside a box)*, the object was a 9 x 12 cm, 4 cm high, semi-transparent plastic box with a lid hinged to it, and with a small toy visible inside: infants had to raise the lid with one hand while grasping the object with the other hand. The 15-month-olds had to turn a small bottle upside down to get a *peg out of a bottle*: the object being an 8-cm-high bottle with an opening of 1.5 cm, and the peg a small wooden 1.8 x 0.8 cm object. Finally, the 18-month-olds' *tool use* task consisted of a 5.5 x 7.2 x 8.5 cm high transparent plastic box, with a lid half-covered by a piece of tape, and a small toy inside the box. The tape prevented the infants from grasping the toy with their bare hands. A wooden stick 2 x 14 cm was placed beside the box, and the task consisted in using the stick as a tool to grab the toy (by means of *Velcro* glued to the object and to one end of the stick).

Insert Figure 1 about here

Each of the five tasks required understanding a different relationship between the object to be grasped and its environment: behind (8 months), inside without need for opening (10 months), inside after opening a lid (12 months), inside after turning upside-down (15 months), inside with the need for a tool (18 months). The actions used for successful retrieval differed from making a detour (at 8 months) to using bimanual simultaneous movements with one hand active and the other hand passive (at 10 months), performing a two-step action with both hands (at 12 months), changing the orientation of the container (at 15 months), and performing a two-step action with a tool (at 18 months).

Procedure

For each age group, two groups of infants were compared: (1) an observation group, and (2) a control group. For the observation group the experimenter directly demonstrated the action three times in a row (using his left hand, then right, then left hand again) out of reach from the infant. In order to avoid the situation to become one of imitation, we introduced a small delay between the demonstration and the test. We arbitrarily chose two minutes for the delay, long enough for immediate imitation to be excluded, but not too long so that the infant would be capable of action recall (Diamond, 1985). During the delay, the infant was given distracters (toys) to play with. After the delay, the infant was presented with the object, and given three trials for the ball grasping task and 30 seconds of manipulation time for the retrieval task. In the control group the infant was given the object before the demonstration, in a pre-observation phase in which three spontaneous trials were allowed for the ball grasping task and 30 seconds of spontaneous manipulation time was given for the retrieval task. Then, to add a within-group to the between-group comparison, the same demonstration of the action was made as for the observation group, and after a two-minute delay with distracters to play with, the object was presented again (test trial). For the demonstration of the grasping task, the emphasis of modeling was on hand orientation and movement dynamics: the experimenter reached for the ball from above with the hand horizontal after a slow, smooth and careful reaching movement. For the retrieval task, the emphasis was on the outcome: the experimenter modeled the task with a movement at normal speed, and showed the retrieved object.

In the observation group, there were eight 8-month-olds (one boy and seven girls), nine 10-month-olds (five boys and four girls), eight 12-month-olds (five boys and three girls), nine 15-month-olds (four boys and five girls), and seven 18-month-olds (five boys and two girls). In the control group, there were nine 8-month-olds (six boys and three girls), nine 10-month-olds (seven boys and two girls), nine 12-month-olds (five boys and four girls), nine 15-month-olds (seven boys and two girls), and seven 18-month-olds (three boys and four girls).

The comparison between the observation group and the pre-observation trial of the control group allowed us to evaluate the effectiveness of observational learning on motor skill as a function of task (grasping vs. retrieval) and age. The comparison between the first trial and the subsequent two trials (ball grasping), or of the first 10 seconds with the next 10 seconds and the last 10 seconds (object-retrieval) in the control group allowed us to evaluate the effectiveness of practice on motor skill. The comparison between the pre-observation and the test trial in the control group was limited since in this case practice and observation effects were combined.

Infants were tested in a quiet room in the presence of their parents (mother, father or both) who were instructed not to intervene with their child during the whole experiment, if possible. Each infant sat on a highchair in front of a table, behind which sat the experimenter. The experimenter presented the objects to the infant on the table and performed the demonstration out of reach. A digital video camera directed at the infant recorded the whole experiment. A frame by frame analysis was later made on all recordings.

Data scoring

For the grasping task the dependent measures were outcome (no try, failure or success), movement time (MT), and qualitative hand preparation (hand orientation and locus of arrival at the object). For the retrieval tasks, the dependent measures were outcome (no try, success and failure), time course of spontaneous successes within 30 seconds, and, when possible, strategies for tentative-retrieval.

Outcome. The trial was coded as "no try" when the infant was interested in something else other than the target object (including the base itself for ball grasping); failure (score = 0) when the infant tried to grasp the ball or to retrieve the object but failed; success (score = 1) when the infant succeeded in grasping the ball or retrieving the object.

Qualitative assessment for hand preparation to grasping (for ball grasping only). We analyzed hand shape in the frame where the infant touched the ball (T) (either the arm stops moving or the object starts moving), and two frames prior (T-2 and T-1). We noted where the hand was relative to the ball (in front, on top, or besides).

Strategies for retrieval tasks. For the *detour reaching* task, the only strategy of failure consisted in banging on the transparent wall. For the *tube out of its container*, some infants put the tube into their mouth and pulled the container away, thus freeing the tube. For the action to be considered as a success, infants had to repeat the task bimanually with success, which they almost never did after this seemingly unintentional success. Different strategies for manipulation were coded for the *toy inside the box* task. Infants could fail from not successfully opening the box, or after a unimanual strategy to open the box with one hand and sneak the same hand inside to try to grasp the object. For the *peg out of a bottle* task, infants who failed usually put their finger into the neck, or just shook the bottle. For the *tool use* task, the main unsuccessful strategy consisted in ignoring the tool and trying to reach for the object with the hand.

Using the videotape recordings, two observers first coded independently for the different measures, until at least a 95% inter-rater agreement was reached.

Statistical analyses

ANOVAs for age (and for trial for the ball grasping task) were calculated using success/failure (0/1) for both tasks, and movement time for reaching for the ball. T-tests for matched samples were added for within age-group comparisons between the two successive trials in the ball grasping task.

Results

Spontaneous success as a function of age

We first ensured that the rate of success did not differ significantly across age groups. This was done by comparing the frequency of success on the first trial for the ball grasping task, and over the whole 30-second trial before demonstration for the retrieval task, as a function of age in the control group.

For the ball grasping task, it can be seen in Table 1 that 8-month-olds had a very low success rate, whereas 57.1% of the 15-month-olds were successful. However, an ANOVA for age (x 5) calculated using success/failure scores (1 vs 0) showed no significant effect for age. For the retrieval tasks, there was a low success rate at eight months of age, and no success at eighteen months. Again, an ANOVA for age (x 5) calculated using success/failure scores (1 vs 0) showed that the age-related difference was not significant. We thus considered that, given that it is extremely difficult to devise perfectly equivalent tasks for different age groups, the comparison of the effect of practice versus observation on learning could quite acceptably be made across ages on our tasks.

Insert Table 1 about here

Learning through practice

Ball grasping task. We compared the frequency of success rates across the three trials in the control group. An ANOVA calculated using the success scores for age (independent measure) and trial (repeated measure), indicated no significant effect for age or for trial, and no significant age x trial interaction. It can be seen in Figure 2 that there was no overall age-related tendency in the frequency of success, and that except for the 8-month-olds, there was no increase in frequency of success between the first trial and the subsequent trials. The 8-month-olds, however, succeeded significantly more often on the second rather than on the first trial, and a student t-test for matched samples showed that the difference between their success scores (0 or 1) on the two trials was significant ($t(7)=-2.6$; $p<.05$). It is difficult to explain the lower success rate of the 15-month-olds on the second trial[1], but it is possible that it be due to the restlessness frequently reported at this age (Kochanska, Tjebkes, & Forman, 1998).

Insert Figure 2 about here

Movement time for reaching for the ball varied between 440 and 1440 msec. We found no significant difference in MT between age groups or across trials.

The qualitative assessment of hand preparation aides the interpretation of the 8-month-old results. On the first trial, 37.5% of the 8-month-olds tried to grasp the ball by approaching it from the front (see Figure 3).

Insert Figure 3 about here

This resulted most of the time in pushing it off its base before it was properly secured in the hand. Failure was significantly related to this strategy (0% success among infants approaching from *in front* vs. 100% success among infants approaching from *above* or *beside* at 8 months). On the second trial, only 20% of the 8-month-olds used this strategy, and the infants who succeeded on the second trial after failing on the first one changed their approach towards the ball (see Table 2). This strategy tended to disappear with age, still being observed in 22.2% of the 10-month-olds, but never in the older infants.

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[1] However an ANOVA for trial (repeated measures) calculated using failure / success rates for the 15-month-olds alone indicated that the effect was not significant.

Insert Table 2 about here

Object retrieval task. For the retrieval task, we compared the first 10 seconds of the 30-second trial, with the following 10 seconds and with the last 10 seconds, to see if infants succeeded after some practice with the object. This analysis revealed that, although the majority of the few successes happened between 10 and 20 seconds after starting the action, the difference in frequency of success between the three time periods was not significant.

Learning by observation

To evaluate the influence of observation we first analyzed the difference in success rate between the pre-observation trials of the control group (first trials with the ball) and the trials of the observation group.

Ball grasping task. The comparison between control and observation groups, all ages considered, showed that the success rate was higher in the first trial of the observation group (63.4%) than in the first trial of the control group (41%). An ANOVA for age (x 5) and group (x 2) calculated using success/failure scores (1 vs 0) showed no effect for age, but an effect for group ($F(1,65) = 4.9$, $p < .05$). There was no significant age x group interaction (see Figure 4).

Insert Figure 4 about here

Movement time did not differ significantly between the observation group and the control group in this task.

We also checked for possible changes in success rate between the pre-observation trial of the control group (third trial) and their test trial after demonstration, even though in this case it is difficult to tease apart the effect from practice and from observation. The results showed that in the control group, the trial following the demonstration was not significantly different from the trial before demonstration neither in terms of success, nor in terms of movement time. It is worth noting that the qualitative assessments of hand preparation indicated that the 8-month-olds from the observation group approached the ball from above (in five out of eight infants) more often than the 8-month-olds in the control group on the first trial (in two out of nine infants).

Object retrieval task. The comparison between control and observation groups, all ages considered, showed that the percentage of successes was higher in the observation group (53.6%) than in the control group (28.6%) (see Figure 5). An ANOVA for age (x 5) and group (x 2) calculated using success/failure scores (1 vs 0) showed an effect for age ($F(4,73)=2.7$, $p<.05$), an effect for group ($(1,73)=7.7$, $p<.01$), and a significant age x group interaction ($F(4,73)=3.3$, $p<.02$). An LSD post-hoc test on the age effect indicated that the effect was due to the difference between 8-month-olds and the other age groups, and an LSD post-hoc test on the age x group interaction indicated that the group effect was due to the 18-month-olds. All 18-month-olds from the observation group succeeded in this task, as compared to none of the infants from the control group.

Insert Figure 5 about here

An analysis of the strategies showed one main difference between the two groups. For the “toy inside the box” task (12-month-olds), infants of the demonstration group showed more attempts to open the box and unsuccessful unimanual strategies to try to grasp the object inside than infants from the control group who tended to simply explore or bang the box.

To compare performance before demonstration of the control group and their test trial (after demonstration), we performed an age x trial (repeated measures) ANOVA on the success rate. This revealed no age effect, but a significant effect for trial ($F(1,37)=19.6$; $p<.0001$), and a significant age x trial interaction ($F(4,37)=8.2$; $p<.0001$; see Table 3). A post-hoc LSD test showed that the difference in success rates between before observation trials and the test trials following observation was significant only at 15 ($p<.05$) and 18 months ($p<.00001$). In terms of strategies, infants of the control group did not notably change their strategy use after demonstration.

Insert Table 3 about here

Discussion

In most developmental studies on imitation or observational learning, the targeted task was the same for infants of different ages. In this study, we wanted to observe the development of observational learning on tasks with comparable level of difficulty for the different age groups. However, devising such tasks is not an easy feat. For the ball grasping tasks, we changed the base on which the ball rested: the older the infant the smaller the base, so that the instability of the same ball increased with age. For the retrieval tasks, we changed the object-environment relationship (behind, inside, etc.) so that retrieval became increasingly difficult (involving detour, bimanual movement, two-step action, tool-use, etc.). We did not succeed in finding tasks which elicit exactly the same success rate in all age groups, but we succeeded at least in avoiding a significant age difference. There was some variation in the spontaneous trials (first trial for ball grasping) for the different age groups; for instance, the ball grasping task was particularly difficult at eight months. This could be expected given previous studies showing that the frequency of successful grasping of an object freely presented to the infant (without being held by the experimenter or secured on a support) increases significantly between six and nine months of age (Fagard, 1998). Additionally, the object retrieval task was often failed at 8 and 18 months. Nevertheless, since there was no significant age effect on the rate of success on either of the two tasks, we decided that we could compare the effects of observational learning versus practice across the different age groups. We also differentially emphasized the modeling for each of the two tasks: the emphasis was on hand orientation and movement dynamics for the ball-reaching tasks, and on the outcome for the retrieval tasks. We expected the age-related changes in observational learning to be different in both tasks.

Learning through practice as a function of task and age. Learning through practice in the control group was observed only for the ball grasping task at 8 months of age. At this age, infants often start their reaching movements without orienting their hand to an object's physical characteristics (von Hofsten & Ronnqvist, 1988; Fagard, 1998). Two main components must be controlled for object grasping: temporal coordination between the acceleration component of the reaching phase and the deceleration component of the grasping phase (Jeannerod, Arbib, Rizzolatti, & Sakata, 1995), and hand preparation in terms of shape and orientation. These components are even more important when grasping an unstable object, since doing so is doomed to fail if the reaching movement is not sufficiently slowed down before touching, and/or if the hand does not arrive at the object with an appropriate orientation. In our case, the instability could not be anticipated on the first trial by the infants. It seems that 8-month-olds failed on the first trial at least partly due to a lack of hand-shaping and poor orientation before touching the ball, which was not the case for older infants. We did not measure hand deceleration, but a lack of deceleration may account for the older infants' failure (and partly for the 8-month-olds'). The facts that 8-month-olds, who did not correctly orient their hand on the first trial, improved from the first to the second trial in hand orientation and in frequency of successful grasps, and that older infants, who were more likely to spontaneously orient their hand properly, did not improve significantly from the first to the second trial, might indicate that it is easier to rapidly modify hand orientation with practice than to change the temporal dynamics of the movement.

We did not observe any learning through practice during the 30-second exploration of the object in the retrieval task. It appears that either infants know right away how to retrieve an object or not, but that they do not discover it, at least within this time frame. It has been observed, for instance, that a longer time for manipulation very rarely helps 10-month-old children in succeeding at the tube/container task if they failed within the first ten or twenty seconds (Fagard & Jacquet, 1989).

Learning by observation as a function of task and age. As was hypothesized, learning by observation showed differing results for the ball grasping task and for the retrieval tasks. For the ball grasping task, intergroup comparison showed that learning through observation was significantly effective for the 8-month-olds only. One reason might be that the spontaneous trials lead to many more failures at that age than at later ages. Another reason might be that an important cause for failure at that age is a lack of anticipatory hand orientation, and that observation is particularly effective for learning how to shape the hand before touching an object. However, observation led to the same frequency of "reaching from above" strategies as practice at eight months, as shown by the qualitative analyses. Thus, observation appears to be as effective as practice in inducing an adapted strategy for approaching the ball at that age. By the time the 8-month-olds reached their third trial, they had corrected their spontaneous strategy, so that the demonstration following this trial induced no better outcome as compared to the trial before demonstration in the intragroup comparison. The between-group comparison indicated that older infants (10-month- to 18-month-olds) tended to succeed slightly more often when they had seen the demonstration first than when they did not but the difference was not significant. One reason for this might be that older infants know how to shape their hand in anticipation of grasping, as opposed to 8-month-olds who do not, and that observational learning has a larger effect on the improvement of hand orientation than on changing the temporal dynamics of the movement. The fact that observing the adult was effective for hand orientation at 8 months, for a change that could also be acquired by practice alone, is in line with observation that infants younger than one year old are capable of deferred imitation when a simple action is involved (Meltzoff, 1988).

For the retrieval tasks, between-group comparison showed that observation was globally effective, but more so for the elder infants. Only at 18 months of age were infants from the observation group significantly better than infants from the control group. The highly significant effect of observation at 18 months is in line with Chen and Siegler's findings (2000), who have reported that 18- to 24-month-old infants almost never spontaneously used novel tools to fetch out-of-reach objects and yet readily did so after seeing a model demonstrate using the tools. However, the mean age of the 18- to 26-month-old infants in Chen and Siegler' study was about 22 months. What we have shown here is that this capacity to learn by observation is already excellent at 18 months of age. The fact that none of the other age groups significantly improved is intriguing. Within-group comparison of the control group indicated that 15-month-olds (as well as 18-month-olds) were significantly more successful after demonstration. In this case, it is difficult to draw a conclusion about the role of observation since practice and observation effects were combined. Despite this, if we note that interindividual differences between the two groups cannot be excluded, the result might indicate that at such an age, observation is more effective once the infant has manipulated the object first. This could be explained by a differential activation of the neural networks involved in the perception of action depending on whether the participant observes with the intention to perform the task or not, as shown in adult brain imaging studies (Grezes, Costes, & Decety, 1999).

We also observed a difference between spontaneous strategy use and strategy use after observation at 12 months of age, even though it did not involve more success in the latter case. These results agree with previous studies showing that understanding the relationship between action and effects of observation increases after 12 months of age (Provasi et al., 2001; Elsner & Aschersleben, 2003).

Conclusions and future directions. In conclusion, observational learning, i.e. learning of a new skill through observation without the possibility for immediate imitation, showed a different age-related pattern for the two tasks, ball grasping and retrieval tasks. Observation had an effect for the ball grasping task at an early stage of reaching when the problem spontaneously encountered by infants is a lack of shaping of the hand, and when a small amount of practice also results in the same improvement. It was not useful however in older infants where the problem may lie in the dynamics of the movement (not enough slowing down before touching the object). Nevertheless, it means that observing other persons dealing with objects around them might well influence some aspects of the building of motor repertoire in infants as young as eight months of age.

For the retrieval task, the usefulness of modeling for task performance clearly increased between 15 and 18 months of age. The fact that modeling the way to retrieve an object (presented in such a way that direct grasping was not possible) became effective after 15 months of age agrees with the few studies which can be compared with ours (Elsner & Aschersleben, 2003; Provasi et al., 2001). However, in our study a delay was imposed between observation and test, which suggests that observational learning, and not only imitation, helps in acquiring complex object-related skills during the second year of life.

What could be responsible for this change in the effect of observational learning on object retrieval in the second year of life? Critical factors in the efficiency of observational modeling are the observer’s cognitive-developmental level (based on processes such as attentional span, coding capabilities, etc.) and motivational orientation (Yando, Seitz, & Ziegler, 1978). In our study, one possibility could be that only after 15 months of age do infants better understand the contingency between observed action and their effects, as they do for their own actions and effects on the environment. Or, perhaps it is that only after 15 months can they transfer this contingency to their own behavior. Another possibility, not exclusive of the first ones, could be that older infants are more likely to pay attention to the relevant parts of the modeled action. Further studies that relate eye tracking of the infants to the demonstrations with the efficiency of observational learning are ongoing.

References

Abravanel, E., & DeYong, N. G. (1997). Exploring the roles of peer and adult video models for infant imitation. *J Genet Psychol, 158*(2), 133-150.

Ashford, D., Davids, K., & Bennett, S. J. (2007). Developmental effects influencing observational modelling: a meta-analysis. *J Sports Sci, 25*(5), 547-558.

Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behavior and Development, 19*(2), 159-170.

Bauer, P. J., Wiebe, S. A., Waters, J. M., & Bangston, S. K. (2001). Reexposure breeds recall: effects of experience on 9-month-olds' ordered recall. *J Exp Child Psychol, 80*(2), 174-200.

Bruner, J. S. (1970). The growth and structure of skill. In K. Connolly (Ed.), *Mechanisms of Motor Skill Development* (pp. 63-94). New York: Academic Press.

Buchholz, L., Bushnell, E., & Yang, D. (2007). *Sensitivity to the Model and Toy in an Imitative Context*. Paper presented at the Society of Research in Child Development,

Carpenter, M., Call, J., & Tomasello, M. (2005). Twelve- and 18-month-olds copy actions in terms of goals. *Dev Sci, 8*(1), F13-20.

Chen, Z., & Siegler, R. S. (2000). Across the great divide: bridging the gap between understanding of toddlers' and older children's thinking. *Monogr Soc Res Child Dev, 65*(2), i-vii, 1-96.

Diamond, A. (1981). Retrieval of an object from an open box : the development of visual-tactile control of reaching in the first year of life. *Society for Research in Child Development Abstracts, 3*(78).

Diamond, A. (1985). Development of the ability to use recall to guide action, as indicated by infants' performance on AB. *Child Dev, 56*(4), 868-883.

Elsner, B. (2007). Infants' imitation of goal-directed actions: the role of movements and action effects. *Acta Psychol (Amst), 124*(1), 44-59.

Elsner, B., & Aschersleben, G. (2003). Do I get what you get? Learning about the effects of self-performed and observed actions in infancy. *Conscious Cogn, 12*(4), 732-751.

Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: a magnetic stimulation study. *J Neurophysiol, 73*(6), 2608-2611.

Fagard, J. (1998). Changes in grasping skills and the emergence of bimanual coordination during the first year of life. In K. J. Connolly (Ed.), *The Psychobiology of the hand* (Vol. Clinics in Developmental Medicine, pp. 123-143). Londres: Mac Keith Press.

Fagard, J., & Jacquet, A. Y. (1989). Onset of Bimanual Coordination and Symmetry versus Asymmetry of Movement. *Infant Behavior and Development, 12*, 229-236.

Fagard, J., & Marks, A. (2000). Unimanual and bimanual tasks and the assessment of handedness in toddlers. *Developmental Science, 3*(2), 137-147.

Falck-Ytter, T., Gredeback, G., & Hofsten, C. von (2006). Infants predict other people's action goals. *Nat Neurosci, 9*(7), 878-879.

Gergely, G., Bekkering, H., & Kiraly, I. (2002). Rational imitation in preverbal infants. *Nature, 415*(6873), 755.

Grezes, J., Costes, N., & Decety, J. (1999). The effects of learning and intention on the neural network involved in the perception of meaningless actions. *Brain, 122 (Pt 10)*, 1875-1887.

Heimann, M., & Meltzoff, A. N. (1996). Deferred imitation in 9- and 14-month-old infants: A longitudinal study of a Sweedish sample. *British Journal of Developmental Psychology, 14*(Pt 1), 55-64.

Herbert, J., Gross, J., & Hayne, H. (2006). Age-related changes in deferred imitation between 6 and 9 months of age. *Infant Behavior & Development, 29*(1), 136-139.

Hofsten, C. v. (1989). Mastering reaching and grasping: The development of manual skills in infancy. In S. A. Wallace (Ed.), *Perspectives on the coordination of movement*. Holland: Elsevier Science Publishers.

Hofsten, C. v., & Ronnqvist, L. (1988). Preparation for grasping an object: A developmental study. *Journal of Experimental Psychology: Human Perception and Performance, 14*(4), 610-621.

Huang, C. T., Heyes, C., & Charman, T. (2002). Infants' behavioral reenactment of "failed attempts": exploring the roles of emulation learning, stimulus enhancement, and understanding of intentions. *Dev Psychol, 38*(5), 840-855.

Iacoboni, M., Woods, R. P., Brass, M., Bekkering, H., Mazziotta, J. C., & Rizzolatti, G. (1999). Cortical mechanisms of human imitation. *Science, 286*(5449), 2526-2528.

Jeannerod, M. (2001). Neural simulation of action: a unifying mechanism for motor cognition. *Neuroimage*, *14*(1 Pt 2), S103-109.

Jeannerod, M., Arbib, M. A., Rizzolatti, G., & Sakata, H. (1995). Grasping objects: the cortical mechanisms of visuomotor transformation. *Trends Neurosci, 18*(7), 314-320.

Kochanska, G., Tjebkes, T. L., & Forman, D. R. (1998). Children's emerging regulation of conduct: restraint, compliance, and internalization from infancy to the second year. *Child Dev*, *69*(5), 1378-1389.

Lockman, J. J. (2000). A perception-action perspective on tool use development. *Child Dev, 71*(1), 137-144.

Meltzoff, A. N. (1988). Infant imitation and memory: nine-month-olds in immediate and deferred tests. *Child Dev, 59*(1), 217-225.

Meltzoff, A. N. (1995). Understanding the Intentions of Others - Reenactment of Intended Acts by 18-Month-Old Children. *Developmental Psychology, 31*(5), 838-850.

Meltzoff, A. N., & Moore, M. K. (1994). Imitation, memory, and the representation of persons. *Infant Behavior and Development, 17*, 83-94.

Meltzoff, A. N. (1988). Infant imitation after a 1-week delay: Long-term memory for novel acts and multiple stimuli. *Developmental Psychology, 24*(4), 470-476.

Meltzoff, A. N. (1988). Infant imitation and memory: nine-month-olds in immediate and deferred tests. *Child Dev, 59*(1), 217-225.

Petrosini, L., Graziano, A., Mandolesi, L., Neri, P., Molinari, M., & Leggio, M. G. (2003). Watch how to do it! New advances in learning by observation. *Brain Res Brain Res Rev, 42*(3), 252-264.

Poulson, C. L., Nunes, L. R., & Warren, S. F. (1989). Imitation in infancy: a critical review. *Adv Child Dev Behav, 22*, 271-298.

Provasi, J., Dubon, C. D., & Bloch, H. (2001). Do 9-and 12-month-olds learn means-ends relation by observing? *Infant Behavior & Development, 24*(2), 195-213.

Rizzolatti, G., & Craighero, L. (2004). The mirror-neuron system. *Annu Rev Neurosci, 27*, 169-192.

Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: the origins of cultural cognition. *Behav Brain Sci, 28*(5), 675-691; discussion 691-735.

Troester, H., & Brambring, M. (1993). Early motor development in blind infants. *Journal of Applied Developmental Psychology, 14*(1), 83-106.

Yando, R., Seitz, V., & Ziegler, E. (1978). *Imitation: A developmental perspective*. New York: Wiley.

Table 1: Spontaneous success, before demonstration (control group) as a function of age, for the grasping and the retrieval tasks (%)

Age group	**8-mo**	**10-mo**	**12-mo**	**15-mo**	**18-mo**
Grasping the ball (1st trial)	12.5	44.4	44.4	57.1	50
Retrieving the object	11.1	33.3	50	44.4	0

Table 2: Relationships between strategy for approaching the ball and outcome at 8 months (%)

	1st trial		**2nd trial**		**3rd trial**	
	In front	Else	In front	Else	In front	Else
Failure	43	57	0	100	25	75
Success	0	100	20	80	25	75

Table 3: Frequency of success (%) on the 30-sec trials before and after demonstration (control group) as a function of age, for the retrieval tasks

Age group	8-mo	10-mo	12-mo	15-mo	18-mo
Before demonstration	11.11	33.3	50	44.4	0
After demonstration	11.11	55.6	44.4	77.8	100

Captions

Figure 1: Objects for the retrieval task for each age group

Figure 2: Success on the ball grasping task as a function of age and practice

Figure 3: Strategies for grasping the ball: in front, on top, or beside

Figure 4: Success at the ball grasping task: comparison between the Control group (1st trial) and the Observation group

Figure 5: Success at the retrieval tasks: comparison between the Control group and the Observation group

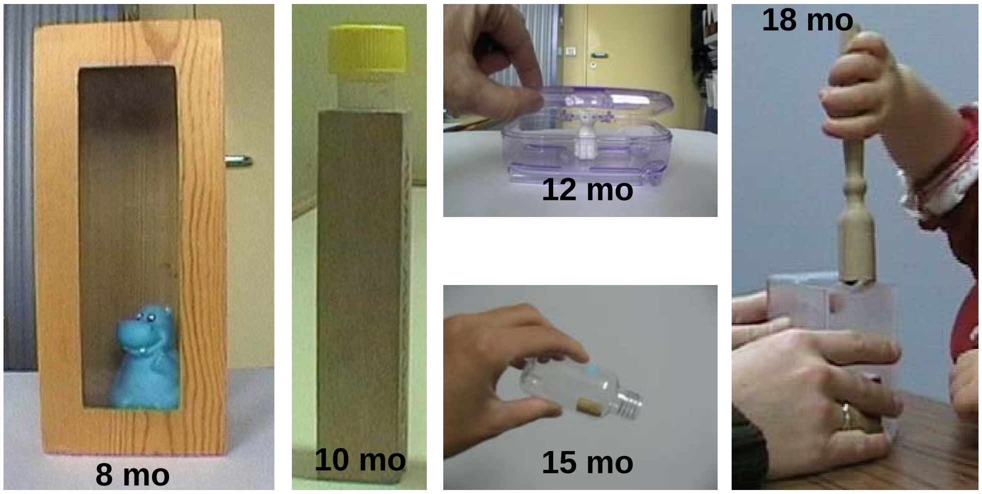

Figure 1

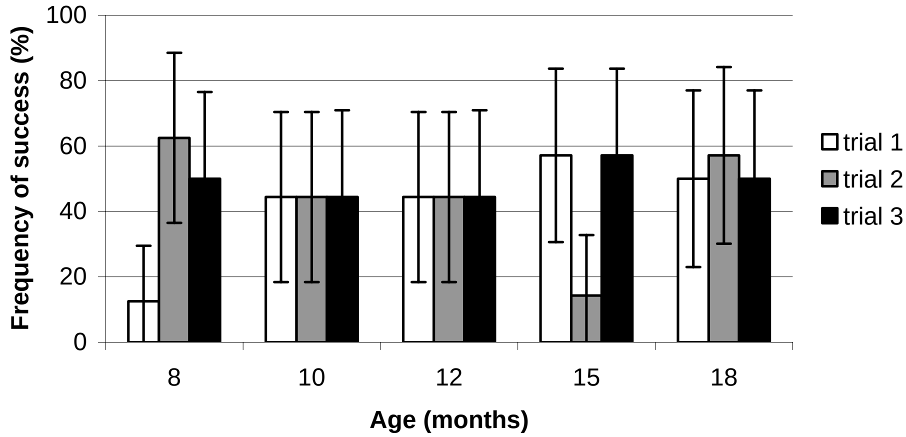
100
80
60
40
20
0
Frequency of success (%)
8
10
12
15
18
Age (months)
trial 1
trial 2
trial 3

Figure 2

Figure 3

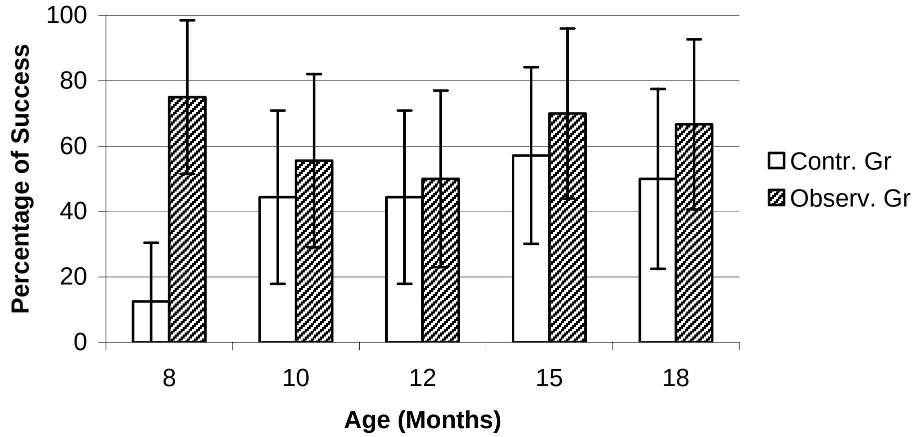
100
80
60
40
20
0
Percentage of Success
8
10
12
15
18
Age (Months)
Contr. Gr
Observ. Gr

Figure 4

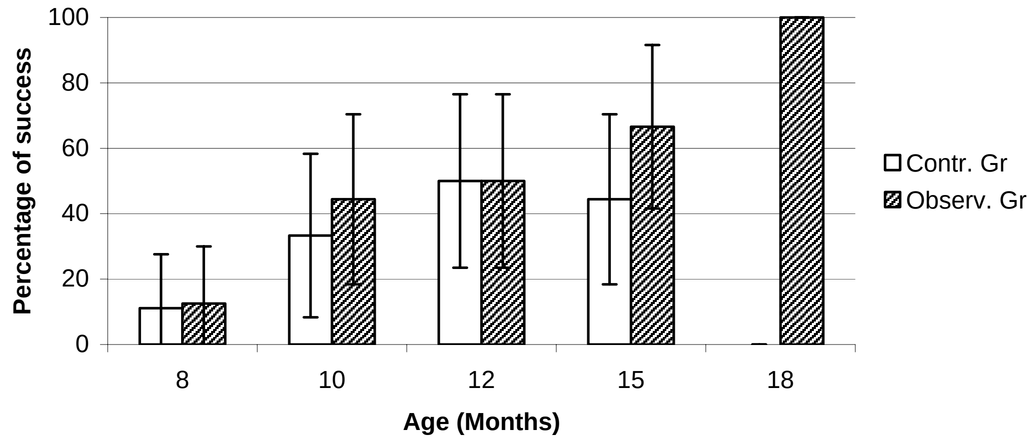
100
80
60
40
20
0
Percentage of success
8
10
12
15
18
Age (Months)
Contr. Gr
Observ. Gr

Figure 5