Journal of Experimental Child Psychology 102 (2009) 14–25

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

The effect of the model's presence and of negative evidence on infants' selective imitation

Ildikó Király *

Department of Developmental Psychology, Institute for Psychology, Hungarian Academy of Sciences, Budapest 1132, Hungary

ARTICLE INFO

Article history:
Received 31 July 2007
Revised 15 June 2008
Available online 19 August 2008

Keywords:
Selective imitation
Ostensive communicative cues
Cognitive transparency
Failed attempt
Social context of imitation
Imitation and memory

ABSTRACT

This study demonstrated selective "rational" imitation in infants in two testing conditions: in the presence or absence of the model during the response phase. In the study, 14-month-olds were more likely to imitate a tool-use behavior when a prior failed attempt emphasized the logical reason and relevance of introducing this novel means, making it cognitively transparent for the infants. Infants also learned imitatively from the cognitively opaque (yet socially communicated) modeling situation, but to a lesser degree. Furthermore, the presence of the model as a social partner during testing influenced the performance of infants in that they were more likely to imitate the novel means when the model was present during testing. These results highlight the important interaction of interpretive schemas (e.g., causality, teleological stance) and social communicative cues in action interpretation guiding imitative learning.

Introduction

Children can copy what others do, and they are ready to learn from others through imitation as early as around the end of their first year (Barr, Dowden, & Hayne, 1996; Killen & Uzgiris, 1981). Based on recent comparative analyses of social learning, it has been argued that the term *imitation* should be applied only to cases in which infants understand the goal of the model's actions, copy the specific actions used by the model, and reproduce the modeled result (Tomasello, 1999; Want & Harris, 2001). Imitation can be contrasted with emulation, where children understand the goal of the model's actions and reproduce the modeled result but do not copy the specific means used by the model. It had been argued previously that most of the time infants *imitate* others' actions (rather than performing

* Fax: +36 13200496.
E-mail address: kiralyi@mtapi.hu

0022-0965/$ - see front matter © 2008 Elsevier Inc. All rights reserved.
doi:10.1016/j.jecp.2008.06.003

emulation) even if a more efficient means is available (Horner & Whiten, 2005; Nagell, Olguin, & Tomasello, 1993; Want & Harris, 2002).

The growing body of evidence in the domain of social learning has also underlined that imitation is an integrated form of cognition that has at least two functions in that it serves (a) as a basic channel for communication (social function) and (b) as a fundamental tool of learning (cognitive function). According to Uzgiris (1981), the main motivation of young infants to copy others' behavior is primarily an epistemic cognitive motivation to support learning about events in the world, whereas older infants are more inclined to imitate others so as to satisfy social motivations, that is, to fulfill a social function of encouraging shared experience with others. From this perspective, "blind imitation," or persistence in copying the specific actions of others in infants, functions (in addition to its epistemic role) as the initiation and maintenance of interaction with the model.

Recently, however, a number of studies have shown that infants do not blindly imitate everything they observe; in some situations, they demonstrate the selective nature of imitation. A classic study of Meltzoff (1995) showed that 18-month-olds did not imitate what an experimenter actually did when she *failed* to achieve a goal; rather, they imitated what she had intended to do. Actually, infants copied the model's means *and* finished the action successfully. An exploratory study of Huang, Heyes, and Charman (2002) examined whether the reenactment of an unsuccessful attempt was due to reading the model's underlying intentions or to learning emulatively from object affordances or spatial contiguity. Interestingly, when all target acts produced within the 20-s response period were counted, 17- and 19-month-olds in the emulative learning and spatial contiguity conditions produced as many target acts as in the full demonstration and failed attempt conditions, revealing the potential effects of nonimitative learning processes. However, when only the infants' first actions were counted, those who observed the full demonstration produced more target acts. Further studies have confirmed that 18-, 24-, and 30-month-olds copy the means that the model uses unsuccessfully to achieve a goal (Bellagamba & Tomasello, 1999; Call, Carpenter, & Tomasello, 2005; Nielsen, 2006). Moreover, it was shown that prior exposure to a failed attempt followed by the full modeling of the target action sequence results in superior performance in the imitation of event components, as compared with receiving only a full modeling of the event (Carpenter, Call, & Tomasello, 2002; Want & Harris, 2001).

On the contrary, after exposure to a failed attempt, 12-month-olds do not use the modeled unsuccessful means but tend to emulate instead (Bellagamba & Tomasello, 1999; Nielsen, 2006). According to Nielsen (2006), in a situation where a prior failed attempt clarified the logic of a new tool-use behavior, 12-month-olds followed the specific actions of the model only when they were given a logical reason to do so; otherwise they focused on reproducing the outcome of the demonstrated actions (i.e., emulation). In contrast, 18-month-olds focused on copying actions and outcomes irrespective of the apparent logic of the model's behavior. Furthermore, 18-month-olds were more likely to copy the actions of the model when she acted socially than when she acted aloof, and 24-month-olds copied the actions of the model irrespective of the model's behavior but were more likely to produce the end result of these actions when the model acted socially.

In a similar vein, Brugger, Lariviere, Mumme, and Bushnell (2007) showed that infants' choice of what to imitate depended largely on their knowledge of the causal relationship between means and outcomes. They found that 14- to 16-month-olds were more likely to imitate the first action of a two-step event sequence when it was physically necessary to generate the effect. In another setup, infants were also more likely to imitate the action when it was socially cued. According to these authors' major conclusion, infants' knowledge of causality and their sensitivity to others' social signals both contribute to their tendency to imitate an action.

Another interesting and significant attempt to demonstrate and interpret selective imitation shows that infants imitate actions in terms of what they believe to be the demonstrator's goal (Bekkering, Wohlschlager, & Gattis, 2000; Carpenter, Call, & Tomasello, 2005). The authors' main result was that infants copied actions in terms of goals. When there was a clearly visible outcome or end state, infants interpreted the outcome as the goal and reenacted it to obtain the same outcome without copying the modeled means; however, when there was no visible end state as a potential goal, infants interpreted the particular action as the goal itself and followed the model's behavior accurately. Hence, according to the authors, infants interpret the action to be reproduced at the hierarchically highest level of action organization in terms of the overall goal.

Gergely, Bekkering, and Király (2002) demonstrated that 14-month-olds engage in "rational imitation." Using Meltzoff's (1988) head-on-box event, Gergely and colleagues tested 14-month-olds' imitative performance in two groups, varying the situational constraints of the model. In the *hands-occupied* condition, the model's hands were visibly occupied while performing the "head action"; in the *hands-free* condition, the model placed her visibly free hands onto the table before demonstrating the head action. When the model's hands were occupied, 14-month-olds were much less likely to imitate the head action (21%); instead, they illuminated the box by touching it with their hand, performing the most simple, easy-to-perform emulative response available to them. In contrast, when the model's hands were free but she still used her head to illuminate the box, 69% of 14-month-olds imitated her head action.

Rational imitation suggests that imitative learning is not an automatic "copying" process invoked by identification with the human actor. Rather, imitative learning is a selective interpretive process that involves the evaluation of the rationality of the means in relation to the situational constraints of the actor. Schwier, van Maanen, Carpenter, and Tomasello (2006) replicated the result of the above study with 12-month-olds using a different but analogous task. In these authors' interpretation of the results, infants' imitative behavior is guided by an understanding of others' intentions as rational choices between available means, and they can use this understanding in cultural learning contexts. In yet another variation of the head-on-box study (Gergely et al., 2002), where infants observed the head touch demonstration in an incidental learning context (with the model not performing any communicative cues toward the infants), infants were less likely to reproduce the head touch action themselves. Most important, the selectivity between the hands-free and hands-occupied conditions disappeared in the absence of ostensive communication (Király, Csibra, & Gergely, 2004).

Researchers in this field agree that the selective interpretive process of imitation is based on an understanding of the situation, whereas it also depends on social communication. In their recent theory, Gergely and Csibra (2005) made a convincing proposal to solve the problem concerning the fast learning of cultural knowledge and, at the same time, introduced imitative learning as its principal means. The model of natural pedagogy assumes that imitative learning is elicited by ostensive communicative cues accompanying the model's manifestations of cultural procedures and knowledge. The interpretive selectivity guiding what aspect of the modeled behavior will be learned through imitation is directed and constrained by the implicit assumptions of the infant's "pedagogical stance" that the other's ostensive cues activate. The main claim of natural pedagogy assumes that in order to interpret and learn from events, infants rely mostly on their own judgment when they comprehend the relevance of an action (with the help of their modes of construal or interpretive schemas), but they weigh the model's cues more heavily when they themselves are unable to figure out the reason for an action. In the former case, the relevance of an action is conveyed by its cognitive transparency, whereas in the latter case (i.e., cognitive opacity), relevance is inferred from the communication of a knowledgeable other. A challenging overall problem and a possible assumption addressed in this study is that the demonstration of a knowledgeable other not only conveys relevance through ostensive communication but also can enhance cognitive transparency and understanding at the same time.

The way imitation is influenced by social communication is still a compelling question. As we can see, ostensive communicative context and social cues facilitate imitation (see also Brugger et al., 2007; Nielsen, 2006). Furthermore, imitation's selective nature disappears in contexts lacking such communicative cues (see Király et al., 2004). In all of the above-mentioned studies, the original form of presentation was varied; during the modeling phase (when infants could code the information), the model either acted socially or was aloof, whereas the social context of the reenactment phase was not controlled. These studies, as a consequence, could not uncover entirely how social cues influenced imitation and whether imitation in these tasks functioned cognitively or communicatively.

Thus, the current study aims to address two important issues in relation to the factors guiding selective imitation in infants. First, it is still an open question whether young infants (12- and 14-month-olds) learn from failed attempts and are able to incorporate the information conveyed regarding the intended goal of the action. The second question relates to how social communicative contexts influence the retrieval phase of imitation, that is, how the presence of a communicative partner influence reenactment in young infants.

To be able to answer the first question, a new design was created where, with the help of communicative cues and through the presentation of negative evidence, the relevance of new information became cognitively transparent; thus, it could be shown that in this case (in contrast to a similar but cognitively opaque situation) a higher level of imitation occurs. In this new design, identical situational constraints were established for the model and for the infant in both conditions. A new variable was introduced to convey overt information on the efficiency (rationality) of the target act; the rationality of the novel action was indicated explicitly by the demonstration of the failure of the alternative prepotent "hand action." It is supposed that this prior failed attempt could help the comprehension of the efficiency of the means used in terms of physical constraints and, simultaneously, could emphasize the availability of the model's prior intention (see Carpenter et al., 2002). In consequence, a prior failed attempt could promote cognitive transparency.

With the objective of responding to the second question, in this study new testing conditions were introduced; whereas during the modeling phase the model always acted socially, during the test phase the model was either present or absent. With the help of this design, the primary function of imitation could be investigated; the model could be conceived either as the source of information or as a communicative partner. If the model is conceived "only" as the source of information, the amount of imitation cannot be expected to decrease in the model-absent testing condition, underlining that imitation serves primarily epistemic purposes.

Groups of 14-month-olds were tested while varying the situational constraints of the model with a new target object, "a ball as a lifter" for a hidden box, in two testing conditions.

Method

Design

The effects of two independent variables on infants' tendency to imitate a novel action were investigated. The first independent variable was whether the model was present or absent during the test phase (*model present* vs. *model absent*), and the second one represented the mode of presentation (*tool successful only, hands unsuccessful–tool successful,* and *hand manipulation control*). The above two factors were crossed in a factorial design, creating six different groups of participants. A *baseline* condition served to assess the spontaneous performance of infants on the new apparatus.

Participants

A total of 94 14-month-olds were recruited through advertisements in local newspapers. Of these, 9 were excluded from the final sample because of technical error ($n = 2$), parental interference ($n = 2$), or failure to come back for the test phase of the study ($n = 5$). Of the 85 participating infants, 62 were assigned to one of four conditions (*model present/tool successful only* [$n = 13$], *model present/hands unsuccessful–tool successful* [$n = 14$], *model absent/tool successful only* [$n = 18$], and *model absent/hands unsuccessful–tool successful* [$n = 17$]) and a further 23 were assigned to hand manipulation control conditions (*model present/hand manipulation control* [$n = 12$] and *model absent/hand manipulation control* [$n = 11$]). The mean age of the infants was 13 months 28 days (range = 13 months 17 days to 14 months 14 days), and their sex distribution was 41 girls and 44 boys.

An additional 14 infants were tested in the baseline condition (mean age = 14 months 5 days, range = 13 months 20 days to 14 months 15 days, 8 girls and 6 boys).

Apparatus

We introduced a small red box ($9 \times 9 \times 9$ cm) with a slightly smaller box hidden inside it ($9 \times 9 \times 5.5$ cm) and a new tool object—"a ball as a lifter." This new tool consisted of a magnet and a ball, with the magnet fixed to the ball (10 cm) on a short string. The hidden box was placed on a small table between the model and the infants during the modeling phase and was presented to the infants at the same location during the test phase. The sessions were monitored and videotaped from behind a one-way mirror.

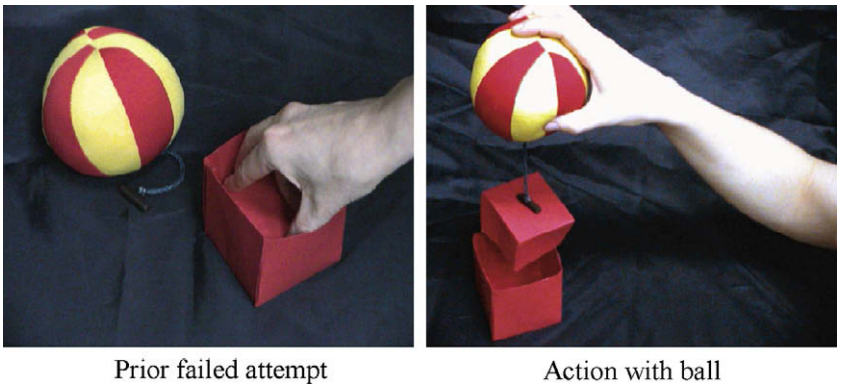

Fig. 1. A ball as a lifter.

Procedure

The infants were brought to the laboratory twice with a 1-week delay between visits. The first session consisted of the modeling phase, and the second session (1 week later) was the test phase of the study. This delay was introduced following the method of Meltzoff (1988), with the overall aim of testing the permanent effect of possible selective imitative behavior.

Modeling phase

The infant was seated on his or her parent's lap in front of the table with the apparatus covered with a cloth. The apparatus was placed approximately 1 m away from the participant to prevent him or her from touching it. The mother was instructed not to interact with her baby during the modeling phase. In each condition (and before each demonstration), the experimenter sat on the opposite side of the table, uncovered the hidden box, and then (as part of a communicative context) looked at the infant, called his or her name, and attracted his or her attention by saying "Look!", making sure that the infant and model were taking part in a joint attention situation.

In the tool successful only condition, the model grasped the ball and lifted the small hidden box out of the slightly larger one by contacting it with the magnet that was hanging from the ball. This event was the core target behavior in all of the experimental conditions. After taking out the smaller box with the ball and magnet, the model grasped the larger box as well and then hid the elements of the apparatus under the table, where she rearranged them and put them back on the table for further demonstrations.

In the hands unsuccessful–tool successful condition, before presenting the very same "lifting with the ball action," the model tried to take the box out with her hand but failed. (This was obviously difficult because the inner box was smaller in height and was inserted tightly into the outer box.) While presenting the failed attempt, the model performed a frown as a sign of her effort. After this failed attempt, the model performed the same successful action with the ball that was presented in the tool successful only condition (see Fig. 1).

In a hand manipulation control condition,[1] the demonstrator touched and pushed the box sideways with two fingers before the same "lifting with the ball action." While presenting this prior manipulation, the model performed the same frown as in the hand unsuccessful–tool successful condition. Thus, in this condition, the box was manipulated twice as in the hands unsuccessful–tool successful condition, accompanied by the same interactional frame, but at the same time this manipulation did not convey information on the efficacy of the hand action.

[1] I thank an anonymous reviewer for suggesting this control condition.

The demonstrator repeated the action sequence three times in each condition, making eye contact with the infant in between these actions and attracting the infant's attention if necessary (calling his or her name and saying "Look!" while alternating his or her gaze between the apparatus and the infant). The demonstrations of the target action sequence were accompanied by an approximately equal amount of verbal interaction in all conditions because attracting the attention of the infants just at the beginning of each demonstration was successful.

Test phase

The infant again was seated on his or her parent's lap, in front of the table with the uncovered hidden box and ball, but this time at a distance that allowed the child to reach it. In the model present condition, the model, who had demonstrated the target action 1 week earlier, sat on the other side and encouraged the infant to play with the apparatus without giving explicit instructions. The infant was told "It's your turn now, you can play!" In the model absent condition, the infant had the opportunity to play with the apparatus in the presence of his or her parent only. The mother was asked to refrain from giving any direct instruction with respect to the modeling phase and apparatus but was instructed to encourage the infant to play with the apparatus (using the very same instruction: "It's your turn now, you can play!").

Baseline condition

To assess the spontaneous production of the target action (lifting with ball or any other attempt to contact the ball and box) in the absence of adult demonstration, a baseline control group of 14 infants was exposed to the apparatus in the presence of an adult experimenter.

Data analysis and scoring

The video recordings of the test phase were scored by two independent observers who were uninformed as to which of the four conditions (tool successful only, hands unsuccessful–tool successful, hand manipulation control, or baseline) the participants belonged. The dependent measures were whether the infants attempted to get the hidden box with their *hand* or with the *ball* (or, if both mean behaviors appeared, their relative order) within a 20-s time window. (This time window was used following the method of Gergely et al., 2002, and Meltzoff, 1988.) The coders needed to decide according to the following criteria: A ball attempt was defined as a visible effort to contact the magnet or the ball with the hidden box, whereas a hand attempt was defined as an obvious trial to take out the little box with the hand. The precise exact execution of the modeled behavior was difficult for the infants; therefore, all of the cases where infants tried to use the ball as a lifter (e.g., contacting the hidden box directly with the ball, gripping the magnet and using it to take out the box), independent of whether their action was successful or not, were coded as imitation of the target behavior. Unsuccessful trials can represent understanding the goal of the modeled behavior, yet they fail to bring about the precise behavior and end state (Call & Carpenter, 2002). There was 98% agreement between the two independent coders, $\kappa = .939$, $p < .001$.

Results

The proportion of infants who performed the target action (the action with the ball) in each condition is presented in Table 1. When the model was present during testing, 93% of infants in the hands unsuccessful–tool successful presentation condition, 54% of infants in the tool successful only condition, and 50% of infants in the hand manipulation control condition reenacted the ball action. When the model was absent during testing, 65% of infants in the hands unsuccessful–tool successful presentation condition, 22% of infants in the tool successful only condition, and 35% of infants in the hand manipulation control condition tried to use the target ball action. In the baseline condition, in the presence of an experimenter, only 14% of infants used the ball as a lifter.

An overall analysis of the proportion of trials imitated was performed on 3 (Presentation Condition: hands unsuccessful–tool successful, tool successful only, or hand manipulation control) $\times$ 2 (Test Condition: model present or model absent) factors with the help of the generalized linear model (a general

Table 1
Percentage of infant imitators in each condition

	Hands unsuccessful–tool successful	Tool successful only	Hand manipulation control	Baseline	Overall
Model present	93% (13/14)	54% (7/13)	50% (6/12)	14% (2/14)	53% (28/53)
Model absent	65% (11/17)	22% (4/18)	35% (4/11)		41% (19/46)
Overall	78% (24/31)	36% (11/31)	43% (10/23)		

Note. The values in parentheses represent the numbers of infant imitators out of all participants.

logistic model for binary variables in SPSS 15). This analysis yielded a main effect of presentation condition, Wald $\chi^2 = 17.125$, $df = 2$, $p < .001$, and a main effect of test condition, Wald $\chi^2 = 6.072$, $df = 1$, $p = .014$.

Pairwise comparison of the presentation conditions revealed stronger imitation tendency in the hands unsuccessful–tool successful condition than in the other conditions: hands unsuccessful–tool successful/tool successful only condition, Bonferroni $p = .001$, hands unsuccessful–tool successful/hand manipulation control condition, Bonferroni $p = .011$. There were no significant differences between the other two presentation conditions.

Pairwise comparison of the test conditions showed a stronger imitation rate in the model present condition than in the model absent condition, Bonferroni $p = .014$. This analysis showed that the presence of the model during the test phase led to more frequent imitative behavior in the experimental conditions.

The impact of adult demonstration on the occurrence of target ball actions was assessed through comparing each experimental group with baseline. There was superior performance of a tool-use behavior in comparison with the baseline condition only in the hands unsuccessful–tool successful condition both when the model was present and when the model was absent during testing, model present/hands unsuccessful–tool successful versus baseline, Bonferroni $p < .001$, model absent/hands unsuccessful–tool successful versus baseline, Bonferroni $p = .015$.

The proportion of infants who performed the prepotent hand action (as a naturally available means behavior to attain the goal) in each condition, irrespective of whether the infants also used the ball as a tool, is presented in Table 2. When the model was present during testing, 36% of infants in the hands unsuccessful–tool successful presentation condition, 85% of infants in the tool successful only condition, and 91% of infants in the hand manipulation control condition used their hands to attain the goal of the action, whereas when the model was absent during testing, 47% of infants in the hands unsuccessful–tool successful presentation condition, 84% of infants in the tool successful only condition, and 73% of infants in the hand manipulation control condition tried to take out the little hidden box with their hands.

The overall analysis of the amount of hand actions (as prepotent actions with respect to goal attainment) was performed on 3 (Presentation Condition: hands unsuccessful–tool successful, tool successful only, or hand manipulation control) $\times$ 2 (Test Condition: model present or model absent) factors and revealed a main effect of presentation condition, Wald $\chi^2 = 19.653$, $df = 2$, $p < .001$. According to post hoc pairwise comparisons, there was a significantly lower level of hand actions in the hands

Table 2
Percentage of infants who performed goal-directed hand action in each condition

	Hands unsuccessful–tool successful	Tool successful only	Hand manipulation control	Overall
Model present	36% (5/14)	85% (11/13)	91% (11/12)	69% (27/39)
Model absent	47% (8/17)	84% (15/18)	73% (8/11)	67% (31/46)
Overall	42% (13/31)	84% (26/31)	82% (19/23)	

Note. The values in parentheses represent the numbers of infants who performed the goal-directed hand action out of all participants.

Table 3
Percentage of infant actors in each group

	Goal-directed hand action	Hand action and then ball action	Ball action and then hand action	Ball action
Model present/Hands unsuccessful–tool successful	7%	—	29% (0)	64% (28%)
Model absent/Hands unsuccessful–tool successful	18%	6% (0)	24% (12%)	35% (6%)
Model present/Tool successful only	46%	15% (8%)	24% (16%)	15% (0)
Model absent/Tool successful only	62%	5% (5%)	17% (5%)	—
Model present/Hand manipulation control	50%	16% (8%)	25% (16%)	9% (9%)
Model absent/Hand manipulation control	47%	—	26% (9%)	9% (9%)

Note. The values in parentheses represent the percentages of successful ball actions with respect to all participants in the condition.

unsuccessful–tool successful condition than in the tool successful only presentation condition, Bonferroni $p < .001$, and also compared with the hand manipulation control condition, Bonferroni $p = .001$, whereas there was no significant difference between the tool successful only and hand manipulation control conditions. Infants tried to use their hands to achieve the goal less frequently in the hands unsuccessful–tool successful condition than in the tool successful only and hand manipulation control conditions.

The proportions of cases where only hand or ball actions were used, or where both hand and ball actions were produced (as well as their relative order), are presented in Table 3. In the model present/hands unsuccessful–tool successful condition, 64% of infants tried to imitate the modeled ball action without trying to use their hands despite the fact that only 28% of the ball actions (with respect to all participants in this condition) were successful; an additional 29% of infants in this condition tried to use the ball and then used their hands. In the model absent/hands unsuccessful–tool successful condition, 35% of infants tried to attain the modeled goal only with the ball, and only 6% of them were successful. These proportions were much lower in the other presentation conditions, with 15% of infants in the model present/tool successful only condition, no one in the model absent/tool successful only condition, and 9% in the hand manipulation control condition (both when the model was present and when the model was absent) producing the ball action first.

Differences in the patterns of using just the ball, using the ball first and then the hand, or using the hand prior to using the ball were tested with respect to the experimental conditions. This analysis revealed significant differences, Kruskal–Wallis test ($\chi 2$) = 24.102, $df = 5$, $p < .001$. Pairwise comparison of test conditions revealed that in the hands unsuccessful–tool successful condition, a greater proportion of infants executed the target ball action first or alone compared with the other presentation conditions: hands unsuccessful–tool successful versus tool successful only, Mann–Whitney $U = 33.0$, $p = .004$; hands unsuccessful–tool successful versus hand manipulation control, Mann–Whitney $U = 23.5$, $p = .001$; tool successful only versus hand manipulation control, Mann–Whitney $U = 72.5$, *ns.* In general, the occurrence of the ball action first or alone in the model present testing condition was more frequent than in the model absent testing condition, Mann–Whitney $U = 611.0$, $p = .008$.

Importantly, in the hands unsuccessful–tool successful condition, there was only one case (6% in the model absent condition) when the order of the appearance of hand and ball actions followed the original order of presentation (the hand action preceding the action with the ball); in the hand manipulation control, two infants (16%) enacted a hand trial prior to a ball action.

In the case of the current apparatus, the new tool-use behavior turned out to be slightly difficult for the infants. The percentage of successful ball actions (regarding all of the participants in each condition) is also presented in Table 3. Overall, the amount of successful ball actions was low (5–28%). Most of the infants in the hands unsuccessful–tool successful condition kept on trying to use the ball as a lifter in alternative forms (e.g., contacting the hidden box directly with the ball, gripping the magnet and trying to use it) rather than using just their hands instead. This pattern of results does not appear in the other conditions, where infants tended to use their hands in addition to using the ball to attain the goal.

Discussion

This study has demonstrated selective "rational" imitation in infants in two testing conditions: the presence or absence of the model during the response phase. We could show different patterns of imitation, namely, selective imitation with respect to the inherent logic of the modes of presentation. The results suggest that in the hands unsuccessful–tool successful condition, infants inferred from the model's initial failed attempt that the subsequent ball-with-magnet action was the most effective means available in the situation to achieve the goal of lifting the box.

This design was different from, but analogous to, the original setup of Gergely and colleagues' (2002) study. In one of the presentation conditions (tool successful only), the rationality or effectiveness of the new means, in this case the unknown tool, was not explicit, and thus not easily interpretable in the situation, because for infants the availability of the model's hands could imply that the prepotent hand action might be the most efficient means to perform the task. Here too, as in the hands-free condition of the original head-on-box study (see Gergely et al., 2002; Király & Gergely, 2002), the model's unexpected choice (i.e., the use of a new tool) could mark the "action with ball" as new and relevant information that the ostensive communicative manifestation conveyed. The unexpected new means was cognitively opaque, but by being presented in a communicative context, it was highlighted as relevant information that is worthwhile to learn and follow.

The other mode of presentation (hands unsuccessful–tool successful) in the current design, on the contrary, emphasized the ineffectiveness of the prepotent hand action compared with the new means. Therefore, the main prediction on the basis of the model of selective imitation would be that the amount of imitation in this case will be even higher than in the tool successful only presentation condition. The reason for this claim is that, besides the manifested significance of the new means (which is conveyed by the ostensive communicative context), the presented negative evidence explains its use by highlighting the intended goal of the action and also making obvious the physical ineffectiveness of a hand action. This makes the new act cognitively transparent for infants. Infants performed the modeled new tool-use behavior more frequently in this presentation condition (both when the model was present and when the model was absent during testing) than in the baseline condition, strengthening the claim that the high level of imitation found in this presentation condition confirmed the above prediction.

In this design, the alternative explanation that imitation occurs only in the case of nonrational unusual actions would not predict any difference in imitation in the two presentation conditions given that the very same unusual target action appeared in them within the same situational constraints for the model and the infants.

The inherent logic of the contrast between the two modes of presentation introduced above might raise an alternative explanation. The main argument of this claim is that in the hands unsuccessful–tool successful condition, the attention of the infants was drawn to the box twice during demonstration. The additional prior hand act (even though it failed) could enhance the coding of the new tool through encountering more manipulation with the box[2]; thus, it is conceivable that infants imitated the ball action more frequently because both the box and the ball became more salient in that condition.

A further clue regarding the possible stimulus-enhancing effect of the demonstration in the hands unsuccessful–tool successful condition is given by recent research focusing on children with autism. Somogyi (2007) used the hidden box paradigm to capture how these children interpret others' actions. The results show that nonverbal low-functioning children with autism, unlike typicals, produce the hand action significantly more frequently in the hands unsuccessful–tool successful condition. This pattern of responses demonstrates that in these children the two-step manipulation of the objects did encourage imitation of both the hand and ball actions. However, these results also show that these children, unlike typicals, did not interpret the hand action as a failed action (indicating that it is not possible to take out the hidden box with the hand).

With the aim of ruling out the possible explanation of stimulus enhancement, a hand manipulation control condition, in which a prior hand manipulation appeared without a clear trial to take out the

[2] I thank an anonymous reviewer for proposing this alternative explanation and suggesting how to control for it.

box, was introduced within the very same communicative context. The proportion of imitators in this condition was significantly less than in the hands unsuccessful–tool successful condition (close to the amount of imitation in the tool successful only condition in both the model present and model absent testing conditions). In contrast, the amount of hand actions was significantly higher in this condition than in the hands unsuccessful–tool successful condition (as much as in the tool successful only condition in both the model present and model absent testing conditions). This pattern of results strengthens the claim that the prior hand attempts can serve as bases for inference for infants. Whereas in the hand manipulation control the prior manipulation only emphasized that the model was able to use her hand, in the hands unsuccessful–tool successful condition the prior failed attempt demonstrated that the hand was ineffective; hence, it was worth following the model's tool-use behavior as a more relevant means.

In addition, the occurrence of the target action was above baseline in the hands unsuccessful–tool successful mode of presentation conditions, indicating that there was imitative learning in these conditions. The above results underline that understanding the physical–causal efficiency of a new and relevant means results in an even higher amount of imitation. Thus, in this study, we could confirm the differential degree of imitation with respect to the effectiveness of a new tool-use behavior.

Interestingly, the presentation of the hands unsuccessful–tool successful and hand manipulation control conditions consisted of two steps (in contrast to the one-step tool successful only condition), so they were more challenging regarding mnemonic competence. Despite this fact, in the hands unsuccessful–tool successful presentation condition we found a higher level of imitation given that the extra information (the additional step) could open a door to better understanding the reason for the action, whereas even in the hand manipulation control the same amount of imitation appeared as in the tool successful only condition. The result that hand actions appeared significantly less often in the hands unsuccessful–tool successful condition, despite the fact that the hand was an "actor" in the presentation, reinforces the explanation that the interpretation of this prior step inhibited the prepotent but ineffective hand action. It also rules out the possibility of blind imitation and underlines the understanding and cognitive transparency of the presentation.

A central result of this study is that a main effect of model presence was found; there was selective imitation in both testing conditions (model present and model absent), whereas there was a decrease in the amount of imitation in the absence of the model during the testing phase. A plausible interpretation of this result is that 14-month-olds do not "blindly" follow the model who acts socially; nevertheless, they profit from her presence during reenactment. First, for young infants, the model as a knowledgeable other functions as the source of information that mediates action learning. Infants at this age drew inferences from the demonstration regarding the efficacy of the available and possible means with respect to goal attainment, and they acted on the basis of this coding of the action. This does not seem to be the case for older infants given that they act more socially, copying the model's behavior with high fidelity irrespective of the relevance of the demonstrated means (Brugger et al., 2007; Horner & Whiten, 2005; Nielsen, 2006). Second, young infants tend to benefit from the presence of the model as a knowledgeable other *and* as a communicative partner during the test phase given that in the course of retrieval the model can modulate the practice of a new tool use by giving feedback and correction on action learning. Thus, although young infants seem to imitate selectively, they still rely on social cues, taking the chance to learn from the model about the world. Consistent with the model of natural pedagogy (Gergely & Csibra, 2005, 2006), a communicative context facilitates the acquisition, and thus the transmission, of new and relevant means.

The presented results add to a growing body of literature demonstrating the importance of selective interpretation behind imitative learning. For example, Nielsen (2006) documented selective imitational performance in 12-month-olds using failed attempts as a source of information for the logical reason of a tool-use behavior. His results emphasized that imitation occurs after a prior failed attempt; otherwise, infants emulatively use their hands to solve the problem. In our case, regarding all of the presentation conditions, there was imitative learning when the model was present during the response phase. However, it was performed at different levels depending on alterations in the cognitive transparency of the actions modeled. Brugger and colleagues (2007) demonstrated that a physically necessary prior step resulted in a more elaborate organization of a two-step event sequence. Similarly, in our study, a prior unsuccessful act (which was not, however, part of the modeled one-step target

action) revealed a deeper understanding of the new means behavior. Furthermore, this study confirmed that the selective encoding of the different contextual information has long-term effects in that infants imitated selectively after a longer 1-week delay.

In addition, the results of this study expand our knowledge of the way social cues influence imitative behavior. Previous studies reported that 14- and 16-month-olds not only copied actions that were sufficient to arrive at the end state of the demonstrated action sequence but also copied inefficient actions if they were modeled in a communicative context (Brugger et al., 2007). Furthermore, 18-month-olds were more inclined to copy the specific actions of a model when she was engaged than when she acted aloof during presentation (Nielsen, 2006), and 18-month-olds copied the novel actions of a model regardless of the apparent logic of the demonstration in an ostensive communicative context (Király et al., 2004). In another study, 24-month-olds' tendency to copy the model's specific actions was not influenced by her social disposition (disinterest) during modeling, although their actions were more successful when the model acted socially (Nielsen, 2006). What is common in these studies is that they all investigated the role of a social communicative context during the modeling phase, and thus the period of coding, in imitative learning. Our study revealed that social communicative cues, such as the presence of the model, can play a crucial role in learning through imitation during the retrieval phase as well.

Our results, however, are challenged by the age-related changes that the above-mentioned studies uncovered. Whereas younger infants imitate selectively, copying primarily to satisfy cognitive motivations and learn about events in the world (as in our study), older infants seem to imitate to fulfill social motivations and upgrade shared experience.

As a further interesting piece of evidence, Horner and Whiten (2005) found that 3- and 4-year-olds reproduced both irrelevant and relevant actions with high fidelity, indicating that the availability of causal information did not influence the social learning strategy they employed. Moreover, their tendency to imitate was not influenced by the fact that the model left the room at the time of testing. Thus, it seems plausible that the logic of a model's demonstration and the communicative cues she provides influence differentially how children engage in social learning at different ages.

The difficulty of successfully reproducing the modeled new target behavior is another possible limitation of the current results. Thus, it is still an open experimental question as to how infants would engage in imitative learning in the case of an easy-to- perform new tool-use behavior.

In sum, differential imitation in the three presentation conditions in this study suggests that imitative learning is a selective interpretive process involving the evaluation of the rationality of the means in relation to the situational constraints of the actor. These results also serve as a proof of sensitivity to communicative relevance in imitation. In addition to pointing to what is relevant and new information in the situation, the presentation of a failed attempt in an ostensive communicative context even makes transparent why it is relevant. In our case, the prior failed attempt with the hand explained the model's contrastive choice; it helped to find out the overall goal of the situation (for a similar argument, see Carpenter et al., 2002) and, at the same time, informed the observer about the physical ineffectiveness of the available prepotent means.

Acknowledgments

The research outlined in this article was supported by an FP6 grant ("EDICI") to the research team of the Institute for Psychology, Hungarian Academy of Sciences, led by György Gergely, and a grant from OTKA to Ildikó Király (T 047071). I thank György Gergely for his comments on the manuscript and thank Kata Egyed, Kata Krekó, Krisztina Kupán, Eszter Somogyi, and Rita Kéri for their contributions. Some of the data were presented at the 13th biennial meeting of the International Conference on Infant Studies (ICIS), Toronto, Canada, in 2002.

References

Barr, R., Dowden, A., & Hayne, H. (1996). Developmental changes in deferred imitation by 6- to 24-month-old infants. *Infant Behavior and Development, 19*, 159–171.

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

Bellagamba, F., & Tomasello, M. (1999). Re-enacting intented acts: Comparing 12- and 18-month-olds. *Infant Behaviour and Development, 22*, 277–282.
Brugger, A., Lariviere, L. A., Mumme, D. L., & Bushnell, E. W. (2007). Doing the right thing: Infants' selection of actions to imitate from observed event sequences. *Child Development, 78*, 806–824.
Call, J., & Carpenter, M. (2002). Three sources of information in social learning. In K. Nehaniv & C. L. Nehaniv (Eds.), *Imitation in animals and artefacts* (pp. 211–228). Cambridge, MA: MIT Press.
Call, J., Carpenter, M., & Tomasello, M. (2005). Copying results and copying actions in the process of social learning: Chimpanzees (Pantroglodytes) and human children (Homo sapiens). *Animal Cognition, 8*, 151–163.
Carpenter, M., Call, J., & Tomasello, M. (2002). Understanding "prior intentions" enables 2-year-olds to imitatively learn a complex task. *Child Development, 73*, 1431–1441.
Carpenter, M., Call, J., & Tomasello, M. (2005). Twelve- and 18-month-olds copy actions in terms of goals. *Developmental Science, 8*, F13–F20.
Gergely, G., Bekkering, H., & Király, I. (2002). Rational imitation in preverbal infants. *Nature, 415*, 755.
Gergely, G., & Csibra, G. (2005). The social construction of the cultural mind: Imitative learning as a mechanism of human pedagogy. *Interaction Studies, 6*, 463–481.
Gergely, G., & Csibra, G. (2006). Sylvia's recipe: The role of imitation and pedagogy in the transmission of human culture. In N. J. Enfield & S. C. Levinson (Eds.), *Roots of human sociality: Culture, cognition, and human interaction* (pp. 229–255). Oxford, UK: Berg.
Horner, V., & Whiten, A. (2005). Causal knowledge and imitation/emulation switching in chimpanzees (*Pan troglodytes*) and children (*Homo sapiens*). *Animal Cognition, 8*, 164–181.
Huang, C., Heyes, C., & Charman, T. (2002). Infants' behavioral re-enactment of "failed attempts": Exploring the role of emulation learning, stimulus enhancement, and understanding of intentions. *Developmental Psychology, 38*, 840–855.
Killen, M., & Uzgiris, I. (1981). Imitation of actions with objects: The role of social meaning. *Journal of Genetic Psychology, 138*, 219–229.
Király, I., Csibra, G., & Gergely, G. (2004). The role of communicative-referential cues in observational learning during the second year. Poster presented at the 14th biennial International Conference on Infant Studies, Chicago.
Király, I., & Gergely, G. (2002). Imitation of goal-directed acts in infants is a selective interpretative process. Poster presented at the 13th biennial International Conference on Infant Studies, Toronto, Canada.
Meltzoff, A. N. (1988). Infant imitation after a one week delay: Long term memory for novel acts and multiple stimuli. *Developmental Psychology, 24*, 470–476.
Meltzoff, A. N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology, 31*, 1–16.
Nagell, K., Olguin, R., & Tomasello, M. (1993). Processes of social learning in the imitative learning of chimpanzees and human children. *Journal of Comparative Psychology, 107*, 174–186.
Nielsen, M. (2006). Copying actions and copying outcomes: Social learning through the second year. *Developmental Psychology, 42*, 555–565.
Schwier, C., van Maanen, C., Carpenter, M., & Tomasello, M. (2006). Rational imitation in 12-month-old infants. *Infancy, 10*, 303–311.
Somogyi, E. (2007). *The development of intentionality in non-verbal children with autism: A comparative study*. Paris: Université Paris V–René Descartes.
Tomasello, M. (1999). *The cultural origins of human cognition*. Cambridge, MA: Harvard University Press.
Uzgiris, I. (1981). Two functions of imitation during infancy. *International Journal of Behavioral Development, 4*, 1–12.
Want, S. C., & Harris, P. L. (2001). Learning from other people's mistakes: Causal understanding in learning to use a tool. *Child Development, 72*, 431–443.
Want, S. C., & Harris, P. L. (2002). How do children ape? Applying concepts from the study of non-human primates to the developmental study of "imitation" in children. *Developmental Science, 5*, 1–13.