Rational imitation of goal-directed actions in 14-month-olds

György Gergely (113524.2623@compuserve.com)
Institute for Psychology of the Hungarian Academy of Sciences
1132 Budapest, Victor Hugo u. 18-22, Hungary

Harold Bekkering (H.Bekkering@ppsw.rug.nl)
Max Planck Institute for Psychological Research
Amalienstr. 33, D 80799 Muenchen, Germany

Ildikó Király (kiralyi@mtapi.hu)
Institute for Psychology of the Hungarian Academy of Sciences
1132 Budapest, Victor Hugo u. 18-22, Hungary

Abstract

The study sheds new light on the nature of imitative learning in 14-month-olds. It is demonstrated that while infants of this age can indeed imitate a novel means modelled to them, they do so only if the action is seen by them as the most rational alternative to the goal available within the constraints of the situation. The findings support the 'rational imitation' account over current 'imitative learning' or 'emulative learning' accounts in explaining re-enactment of goal-directed action in 14-month-olds.

Introduction

In a well-known study Meltzoff (1988, 1999) demonstrated that 14-month-olds are already capable of delayed imitation of a novel goal-directed action. Infants observed a salient novel action performed by an adult model on a black box with a translucent orange plastic panel for a top surface. The box had a light bulb hidden in it. The model leaned forward from the waist and touched the panel with his/her forehead as a result of which the box was illuminated. The infants were given the box only on a separate visit a week later when 67% of them imitated the salient novel action: they leaned forward themselves to touch the box with their forehead (see Figure 1); an action they would not spontaneously perform (as shown by a control base-line condition). This demonstration indicates the remarkably early presence of imitative learning. Meltzoff argues that 14-month-olds differentiate between the actor's goal (the visible outcome of the box lighting up) and the specific means (head-on-box) performed and "they imitate the means used, not solely the general ends achieved" (1995, p. 509). The present study addresses two important questions that arise in relation to Meltzoff's intriguing demonstration: 1) Why do infants imitate the specific novel action modelled? 2) Why don't they simply push the panel with their hand to achieve the outcome (this being a simpler, more familiar, and easier-to-perform action alternative available to them)?

In his work on the social transmission of tool use in chimpanzees, Tomasello (1999) differentiated between 'imitative learning' – which seems to be a human-specific capacity – and 'emulation learning' that is characteristic of nonhuman primates.

Figure 1: Touching the box with the forehead

Briefly, when primates observe a novel instrumental action that brings about an interesting outcome, they seem to focus on the salient outcome only without differentiating it from the particular means used. This is suggested by the fact that when they attempt to bring about the same outcome themselves – in contrast to young children – they do not directly imitate the specific means modelled. Rather, they perform a series of motor actions directed to the outcome that are already available in their motor repertoire, until – through a process of trial-and-error learning - they hit upon the same effective means that was modelled for them, as if 'reinventing' it by chance.

Tomasello (1999) points out that if infants used emulation learning in the Meltzoff situation, one could expect that instead of imitating the novel and unfamiliar

'head-on-box' action, they would tend to perform a simpler, more natural, and already familiar motor action to achieve the outcome: they would touch the box with their hand (but, apparently, they did not). Therefore, Tomasello (1999) argues that infants in the Meltzoff study "understood a) that the adult had the goal of illuminating the light; b) that he chose one means for doing so, from among other possible means; and c) that if they had the same goal they could choose the same means – an act in which the child imagines herself in the place of the other" According to this simulationist account "imitative learning of this type thus relies fundamentally on infants' tendency to identify with adults…" (p. 82).

At first sight, infants' readiness to faithfully imitate the novel and unfamiliar 'head-on-box' action also seems unexpected in the light of Gergely and Csibra's recent theory of the one-year-old's 'naïve theory of rational action' (Gergely, Nádasdy, Csibra, & Bíró, 1995; Gergely & Csibra, 1997; Csibra & Gergely, 1998). In a series of habituation studies these authors and their colleagues (Gergely et al., 1995; Csibra, Gergely, Bíró, Koós, & Brockbank, 1999) demonstrated that 9 to 12-month-old infants (but not 6-month-olds) can already interpret the behaviour of an abstract computer-animated figure as a goal-directed rational action. For example, infants were habituated to a visual event in which a small circle repeatedly approached and contacted a larger circle by jumping over a rectangular figure (the 'obstacle') that was placed in between them. During the test phase, the 'obstacle' was removed, and infants were presented with either of two events. In the 'old action' event (non-rational approach) the small circle performed the same jumping approach as before to get to the large circle, even though - for adult observers – this jumping-over-nothing action did not seem a 'sensible' goal approach given the absence of the 'obstacle'. In the 'new action' event (rational approach) the small circle performed a novel but (for adults) 'sensible' action: it approached the large circle by following the most direct horizontal straight-line pathway that has become available leading to the large circle. Corresponding to adult intuitions, 9- and 12-month-olds looked longer at the non-rational 'old action' event than at the (rational) 'new action' event, while showing no dishabituation to the latter.

According to Gergely and Csibra's theory this finding demonstrates that when interpreting a goal-directed behaviour, one-year-olds evaluate the rationality of the particular action as a function of the visible goal and the physical constraints of the actor's situation (here the presence of the 'obstacle'). When the situational constraints change (i. e., when the 'obstacle' is removed), infants can infer what particular novel action the actor ought to perform in the new situation to achieve the goal in the most rational or efficient manner. It is hypothesised that in doing so infants rely on the inferential principle of rational action that assumes that to achieve its goal an agent will choose to perform the most rational action available given the constraints of the situation (Gergely & Csibra, 1997; Csibra & Gergely, 1998).

Extending this theory to imitative learning situations one would expect infants to imitate the model's novel means only if it appeared to them to be the most rational or efficient alternative to the goal within the constraints of reality. On this assumption, however, it is not immediately clear why Meltzoff's subjects would consider the novel 'head-on-box' action as the most rational means to the goal, when clearly there is a much simpler, more familiar and for them obviously easier-to-perform motor alternative: they could touch the box simply by placing their hands on it ('hand-on-box' action). Why do they imitate the novel 'head-on-box' action then?

To solve this riddle, we hypothesised that it is possible that the action modelled by Meltzoff contained certain situational features that allowed infants to 'rationalize' the 'head-on-box' action as the most efficient alternative available to the goal. In particular, it seems possible that infants noticed and interpreted the fact that while the model's hands were free to act, s/he nevertheless chose to touch the box with his/her forehead rather than with his/her hands. Assuming that the adult is a 'rational agent', the infants may have concluded that 'there must be a good reason' for this choice, and that the 'head-on-box' action must have advantages over the simpler-looking 'hand-on-box' action in achieving the goal. Therefore, when getting a chance to reproduce the effect, the infants themselves would opt to perform the novel 'head-on-box' action that had been inferred to be the most rational alternative to the goal.

What would happen if the model's hands were visibly occupied while s/he was performing the 'head-on-box' action? This would make it explicit that in the given situation the simpler 'hand-on-box' action is not available to the model, and so the performed 'head-on-box' action would clearly appear to be the most rational alternative to the goal. What would infants do in this case, if after having observed the modelled 'head-on-box' action, we made the box available for them to act on? Note that here the situational constraints on available means would be different in the infant's case than in the case of the adult model, since, unlike the adult's, the hands of the infants would remain free to act. Therefore, while the modelled 'head-on-box' action may have seemed rational for the adult to perform, in case of the infants it would cease to be the most rational alternative available. For them there would clearly be a simpler and more rational means accessible in the form of the familiar and well-practiced 'hand-on-box' action.

Therefore, on the basis of the 'principle of rational action' we would expect that in this situation infants would not faithfully imitate the adult's 'head-on-box' action, but rather they would be more likely to touch the box with their hands: an action that is more rational given the constraints of their own situation.

In sum: our 'rational imitation' account outlined above differs from Meltzoff's and Tomasello's 'imitative learning' accounts in two significant respects. First, the 'imitative learning' model, as it stands, predicts that infants would imitate the particular means modelled by an adult irrespective of whether the specific action is seen as the most rational alternative to the goal or not (cf. Nagell, Olguin, & Tomasello, 1993). In contrast, our 'rational imitation' account emphasizes that infants do not imitate faithfully or automatically an adult model's goal-directed action. Rather, they would first evaluate the modelled behaviour from the point of view of the 'principle of rational action' and imitate it only if they managed to 'rationalize' it as the most efficient alternative to the goal available given the constraints of the particular situation. Second, the 'rational imitation' model predicts that infants will imitate the model's means that was judged to be rational only if the situational constraints of the adult model are similar to those of the infants. If the situational constraints are different, however, and there is a more rational alternative available to the infant that was not available to the model, infants are expected to perform this more rational means rather than imitating faithfully and automatically the specific action modelled by the adult.

We have modified the original Meltzoff (1988) situation in such a way that would allow us to test the above predictions.

Method

Subjects

We tested 30 14-month-old infants (+/- 1 week) in two experimental conditions. Three babies were dropped because they were not brought back for the second test, so overall we report data from 27 infants.

Procedure

The infants were brought to our lab twice with a one-week delay in between. On the first visit infants were seated in their mother's lap in front of a table that had 3 toy objects covered with cloths. (Here we are reporting data only for the 'magic box' object.) The experimenter sat at the other side of the table, while the infants were seated about one meter away from the table so that they could not reach the toys. The sessions were video taped from behind a one-way mirror. On the first visit the experimenter modelled the target act three times making sure that the infant paid attention.

The 'Hands free' condition (n=13) was a slightly modified[1] version of Meltzoff's (1988) original study. In this condition, even though the model's hands were visibly free, she did not use them. Instead, by leaning forward from the waist she touched the lamp on the box with her forehead ('head-on-box' action) and the lamp lit up. Note that in this situation the actor's reason for not using his free hands to touch the box is not directly demonstrated: it is only implied by her choice to use her head rather than her hand to light up the lamp.

In the 'Hands occupied' condition (n=14), before presenting the 'head-on-lamp' action the model, pretending to be freezing, told another experimenter that "she was cold and would like to have her blanket". After it was handed over to her, she wrapped it around her shoulders and held it tightly with both hands. (In the 'Hands free' condition the model also asked for her blanket, but then she put the blanket around her shoulders leaving her hands visibly free in front of her.) Note that in this condition the relevant situational constraints are different in the case of the model than in the case of the infant: while the hands of the adult were occupied, the hands of the infant were free. In both conditions the model went on to perform the very same 'head-on-box' action lighting the lamp by touching it with her forehead. (She repeated this three times.)

The test phase: Infants returned a week later. Sitting in their mother's lap they were allowed to act on the 'magic lamp' themselves. The model sat on the other side of the table as before. The infants actions were videotaped from behind a one-way mirror.

Data analysis and scoring

The video records of the test phase were scored by two independent observers who were uninformed as to which of the two conditions the subject belonged to. If the infant attempted to imitate the 'head-on-box' target action within a 20 sec time window s/he received 1 point, if s/he did not, s/he got 0 point. An attempt was defined as either touching the lamp with the head, or leaning forward in such a way that the subject's head approached the lamp within 10 cm or less (this is

[1] Our 'magic box' was slightly different from the one used by Meltzoff (1988) in that we have mounted a circular translucent table lamp on top of the box that could be activated by touch (see Figure 1). We have used this arrangement because in a pilot study identical to Meltzoff's experiment we noticed that the head and hair of the adult model often blocked the light effect from the infants when she touched the surface of the box with her forehead leaning over it. As a result some of the infants seemed to notice the light effect (showing surprise) only when they themselves touched the box during their second visit. By mounting the circular touch-sensitive table lamp on the box the resulting light effect was clearly visible to all infants already during the modeled action.

identical to Meltzoff's (1988) original criterion). The observers also coded the number of 'hand-on-box' actions and the number of times infants pointed to the model within the 20 sec time window. There was a 97% agreement between the two independent coders.

Results

To test our hypothesis that the different situational constraints on action in the two conditions influence the likelihood of the target action being imitated, we first compared the relative amount of imitated 'head-on-box' target acts in the two conditions. As Figure 2 shows, the two conditions differed significantly in this respect (Chi-square = 6.238 (df=1) p<.013). In the 'Hands free' condition 75% of the infants imitated the modelled 'head-on-lamp' action replicating Meltzoff's original result (he found 67% imitation). In contrast, when the model's hands were occupied ('Hands occupied' condition), only 27% of infants imitated the target act. The rest of the infants tried to light the lamp by touching it with their hands only.

Furthermore, there was a clear indication that the majority of infants who did not imitate the target act in the 'Hands occupied' condition did not fail to do so because they forgot the target act after the one week delay.

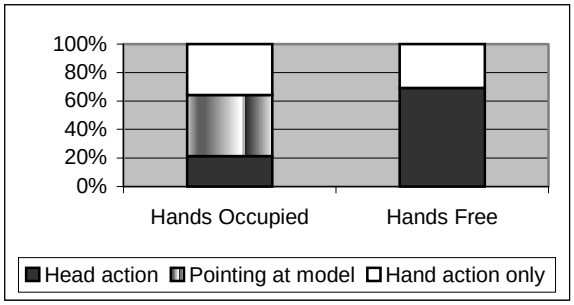

Figure 2:The amount of head and other types of actions in the two conditions

This is shown by the fact that 6 out of the 11 subjects (55%) not imitating the target act in this group produced a playful pointing gesture, pointing to the model (often smiling or giggling) (Figure 3a). This clearly indicates that they did recall the salient 'head-on-box' action of the model. In spite of this, however, they chose not to imitate, but proceeded to make the lamp light up by touching it with their hand (Figure 3b): a means that was simpler and more rational alternativa in their situation than the novel target act modelled. Furthermore, we found that all subjects in both conditions did produce at least once the 'hand-on-box' action within the 20 sec time window. In fact, the 'hand-on-box' action was typically performed more than once (Mean=2.1) by most subjects.

Figure 3a: Pointing to the model

Figure 3b: Touching with hand

Moreover, the large majority of infants (9 out of 12) who re-enacted the modelled action, performed the 'hand-on-box' action before imitating the 'head-on-box' action (Figure 4). Finally, in all cases where a 'hand-on-box' action was performed before the 'head-on-box' action, the hand-on-box' action was successful in bringing about the goal (i.e. the light was illuminated).

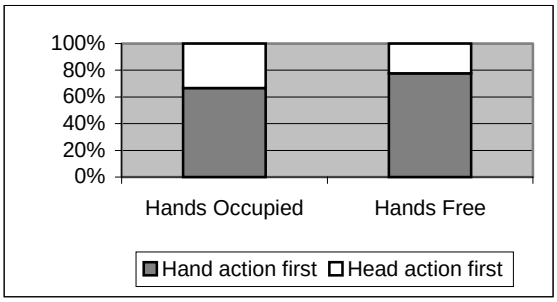

Figure 4: Relative order of hand action vs. head action among imitators

Discussion

The results provide support for the assumptions of the 'rational imitation' account. The differential degree of imitating the same target act found in the two conditions demonstrates that novel goal-directed actions modelled by an adult are not automatically imitated by 14-month-olds. The likelihood of reenacting a novel means observed was clearly a function of the infants'

interpretation of the rationality of the instrumental act in relation to the situational constraints on the actor's possible actions. We found that infants only imitated the 'head-on-box' action, if the contextual constraints of the adult's situation were the same as those of the infants themselves ('Hands free' condition). In this case 75% of the infants imitated the novel action, replicating Meltzoff's (1988) original finding. In contrast, when the model's hands were occupied ('Hands occupied' condition), the very same 'head-on-box' target act was imitated only by 27% of the infants. Given that their own hands were free to act, 73% of the 14-month-olds chose not to imitate the model in this condition, but performed a more rational alternative action available to them: they simply touched the lamp with their hand (Figure 3b).

We find especially informative the fact that in the 'Hands occupied' condition, in which the majority (73%) of the infants did not imitate the novel 'head-on-box' action, more than half of the non-imitating subjects pointed at the model while showing amusement (Figure 3a). This pointing gesture clearly indicates that after a week delay these infants successfully recalled the modelled 'head-on-box' action. Nevertheless, they chose to perform the (non-modelled) 'hand-on-box' action that was seen as a more rational means available to them in their own situation.

But why did the majority of infants reenact the novel 'head-on-box- action after having succeeded in lighting up the lamp by simply pushing it with their hands (Figure 4)? One possibility is that this imitative act served a communicative function: maybe to remind the model after a week that they remembered his funny action or to make him repeat his act. Alternatively, the reenactment may have served an epistemic function. Our data suggest that the infants inferred from seeing the model's free hands that 'there must be some reason' behind his choice to use his head instead of his hands to touch the box. Therefore, they may have expected the 'head-on-box' action to be in some (yet unknown) ways more advantageous. So maybe they reenacted the novel head action to discover the 'reason' behind the model's choice by experiencing the potential differences between the two alternative means. (We are currently running studies to test these hypotheses.)

To conclude:

1. The results successfully extend our 'naive theory of rational action' from the domain of action interpretation to the domain of action production and imitative learning.

2. We have demonstrated that evaluating the rationality of intentional action in relation to visible goals and situational constraints takes place at two different levels: a) during interpreting goal-directed actions performed by others (*ENCODING)*, and b) during selecting an appropriate motor response to achieve the same goal by the self (*RESPONSE GENERATION).*

3. Our findings show that re-enactment of a modelled goal-directed action is not an automatic process triggered by identification with a human actor. While identification may be involved in imitation, it is not sufficient to account for the differential pattern of re-enactment in our two conditions.

4. Instead, re-enactment of intentional action is a selective interpretative process driven by the inferential principle of rational action. Re-enactment takes place only a) if the action is judged as rational given the situational constraints of the *model*, and b) if the action is judged as potentially more rational than other available alternatives given the situational constraints of the *infant herself***.**

Acknowledgements

This research was carried out as part of an ongoing cooperation between the Institute for Psychology of the Hungarian Academy of Sciences and the Max Planck Institute for Psychological Research in Munich.

References

Csibra, G., & Gergely, G. (1998). The teleological origins of mentalistic action explanations: A developmental hypothesis. *Developmental Science, 1*, 255-259.

Csibra, G., Gergely, G, Bíró, S., Koós, O., & Brockbank, M. (1999). Goal attribution without agency cues: the perception of 'pure reason' in infancy. *Cognition, 72*, 237-267.

Gergely, G., & Csibra, G. (1997). Teleological reasoning in infancy: The infant's naive theory of rational action. A reply to Premack and Premack. *Cognition, 63*, 227-233.

Gergely, G., Nádasdy, Z., Csibra, G., & Bíró, S. (1995). Taking the intentional stance at 12 months of age. *Cognition, 56*, 165-193.

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

Meltzoff, A. N. (1995). What infant memory tells us About infantile amnesia: Long term recall and deferred Imitation. *Journal of Experimental Child Psychology, 59,* 497-515.

Nagell, K., Olguin, K., & Tomasello, M. (1993). Processes of social learning in the tool use of chimpenzees (Pan troglodytes) and human children (Homo sapiens). Journal of Comparative Psychology, 107, 174-186.

Tomasello, M. (1999). *The Cultural Origins of Human Cognition*. Cambridge, MA: Harvard University Press