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Do infants bind mental states to agents?

Dora Kampis [a,b,*], Eszter Somogyi [b], Shoji Itakura [c], Ildikó Király [b]

[a] Institute of Cognitive Neuroscience and Psychology, Research Centre for Natural Sciences, Hungarian Academy of Sciences, POB 398, 1394 Budapest, Hungary
[b] Department of Cognitive Psychology, Eötvös Loránd University, Izabella utca 46, 1064 Budapest, Hungary
[c] Department of Psychology, Graduate School of Letters, Kyoto University, Yoshida-Honmachi, Sakyo-ku, Kyoto 606-8501, Japan

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ABSTRACT

Recent findings suggest that infants understand others' preferential choice and can use the perspectives and beliefs of others to interpret their actions. The standard interpretation in the field is that infants understand preferential choice as a dispositional state of the agent. It is possible, however, that these social situations trigger the acquisition of more general, not person-specific knowledge. In a looking-time study we showed an Agent A demonstrating a choice, that only could have been interpreted as preferential based on the perspective (and thus the belief) of the agent, not the observer. Then we introduced a new agent (Agent B), who chose consistently or inconsistently with Agent A; also varying whether Agent B was an adult or a child. Results show that infants expected Agent B (both the adult and the child) to choose as Agent A, but only in the condition where according to Agent A's knowledge two objects were present in familiarization(confirming previous evidence on the importance of contrastive choice). We interpret these results in the following way: (1) infants do not encode the perspectives of other agents as person-specific sources of knowledge and (2) they learn about the object, rather than the agent's disposition towards that object. We propose that early theory of mind processes lack the binding of belief content to the belief holder. However, such limitation may in fact serve an important function, allowing infants to acquire information through the perspectives of others in the form of universal access to general information.

1. Introduction

In everyday life we constantly observe and interpret the actions of others – we make mental attributions and ascribe goals, intentions and dispositions to others. In developmental psychology it has become a question of interest as to when these abilities emerge. Contrary to previous claims that children start to understand the mental states of others around the age of 4 (e.g., Perner, 1991), recent findings suggest that the implicit roots of this ability, also called Theory of Mind (ToM), are already present in the first 2 years of life (Kovács, Téglás, & Endress, 2010; Luo, 2011; Onishi & Baillargeon, 2005; Surian, Caldi, & Sperber, 2007). However, it is not clear how these early competences are related to the full-blown ToM capacities (for a thorough conceptual review, see Rakoczy, 2012).

Indeed, infants are able to interpret the actions of agents as goal-directed from a very early age (e.g., Csibra, 2008; Gergely & Csibra, 2003; Gergely, Nádasdy, Csibra, & Bíró, 1995; Luo & Baillargeon, 2005; Southgate, Johnson, & Csibra, 2008; Woodward, 1998). In her seminal study, Woodward (1998) habituated infants to an event in which a hand grasped one of two toys. After habituation, the location of the objects was reversed and the hand then grasped either the old object in the new location or the new object in the old location. Results showed that the infants were surprised at the test events in which the hand grasped the new toy, suggesting that infants at 5–6 months of age encoded the goal of the action (the old object) and expected the hand to act accordingly.

* Corresponding author. Present address: Cognitive Development Center, Central European University, Hattyú u. 14, H-1015 Budapest, Hungary

E-mail address: Kampis_Dora@ceu-budapest.edu (D. Kampis).

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Realizing that actions are performed to reach a certain goal is the very basis of understanding the actions of agents. Since goals tend to be determined by the dispositions of the person acting, a second step is to understand that goal-directed actions are likely to be driven by certain dispositions. Recent findings (Luo & Beck, 2010; Song, Baillargeon, & Fisher, 2005) show that infants are capable of attributing dispositions to agents by around the first year of life. Using a modified Woodward-paradigm, Luo and Baillargeon (2005) habituated infants to a self-propelled box, which approached a cone in two conditions. In the control condition there was no other object present during familiarization. However, in the test condition, a second object, a cylinder was present, but was never approached by the box. Results showed that after the locationswitch in the test phase infants expected the box to approach the cone, but only when there was another object present during familiarization, suggesting that only in this case they attributed to the box the preference of the cone over the cylinder. Nevertheless, infants had no expectations about the action of the box in the one-object control condition, indicating the role of contrastive choice in attributing preferences. If, during the familiarization phase, only one object was present, the box could not make a real choice (since there was no other object that the box *did not* choose). Therefore, infants did not interpret the action of the box as an expression of preference; hence they could not predict the action of the box when a new object appeared.

In order to interpret an agent's actions, it is not always sufficient to determine the goals and dispositions of the agent; rather, under certain conditions, it is crucial to be aware of what the agent *knows* about the situation. Studies that create a knowledge gap between the infant and the agent about the situation show that infants are not only able to consider the agent's perceptual access when interpreting her actions, but they develop their expectations accordingly (Caron, 2009). Sodian and Thoermer (2004) found that 12-month-olds acted surprised when an agent incorrectly labeled an object after the agent had seen the object, but not if the agent had not had any perceptual access to it. Furthermore, in the experiment of Luo and Beck (2010), 16-month-old infants were firstfamiliarized to an agent choosing a red object over other objects. In the test phase, screens of different colors (red on one side, green on the other) were introduced between the agent and the infant, thus the perceived color of the screen was different for them. Results showed that infants developed an expectation of the agent's choice in the test phase according to the agent's perspective, suggesting that they could determine what the agent could see and used that information when developing their expectations.

In the above-mentioned experiments (e.g., Luo & Baillargeon, 2005 and Luo & Beck, 2010), infants interpreted the agent's actions as an expression of preference towards a certain object. However, it seems that this is only the case if the agent chooses a particular object over one or more other objects. Taking advantage of this feature of contrastive choice, Luo and Baillargeon (2007) designed an experiment in which they manipulated the agent's perceptual access and therefore created various possible interpretations of the scene from the side of the infants. In the familiarization phase, infants saw an agent reach repeatedly for Object A over Object B. Object B was either (1) visible to both the agent and the infant, (2) hidden from the agent behind a screen but visible to the infant, or (3) placedbehind the screen by the agent (so the agent knew it was there but no longer saw it). In the test phase, the objects' position was switched and both were visible to the agent and the infant. Results showed that the infants expected the agent to continue to reach for Object A in the test phase only if in the familiarization (a) both objects were present or (b) the agent placed the other object behind the screen. If the agent did not know about the presence of Object B, the infants did not interpret the action of the agent as the expression of his or her preference. This confirms the role of contrastive choice and suggests that infants were able to take the perspective of the agent as a basis for interpreting his or her actions. In a related study (Luo & Johnson, 2009), 6-month-olds showed a similar pattern, demonstrating that very young infants are able to understand preferential choice and can use the perspectives of others todetermine whether they have knowledge of certain objects to interpret their actions.

Moreover, building further on the results of Luo and Baillargeon (2007), in a subsequent study Luo (2011) introduced an experimental situation in which an agent falsely (or truly) *believed* that two objects were present in a setup. In the orientation trial, the agent herself positioned an object behind an opaque, or a transparent screen, and this object was subsequently removed. This removal was either visible (true belief one-object condition) or invisible (false belief two-object condition) for the agent. In familiarization trials, the agent chose the other object, in front of the second, always-transparent screen. The question was whether infants in test phase would attribute a preference to the agent, despite the fact that the infants themselves could only see one object during the choice (false belief two-object condition). Theresults show that 10-month-olds could figure out the basis of the agent's choice by inferring the beliefs of the agent in the situation. Based on this finding, the author suggested that even preverbal infants behave as though they can consider the *mental states* of others when making inferences about their actions.

From these results, one could conclude that infants encode the preferential choice of the agent as the expression of the agent's unique attitude towards that object. In this sense, the information acquired by the infants would be a highly specific, person-centered knowledge about the preference of that particular agent, which would only be useful in a limited number of situations. There is, however, a theoretical approach that allows a different interpretation. Egyed and her colleagues (Egyed, Király, & Gergely, 2013; Gergely, Egyed, & Király, 2007) argued that the interpretation of the expressions of referential attitudes is underdetermined. That is, a referential situation can allow more than one way of understanding the observed action. One view is the above-mentioned person-centered explanation, which leads to the acquisition of person-specific knowledge. Another interpretation isobject-centered, meaning that infants learn new information about the referent (about the particular object that was referenced). The former approach considers the content of the emotional expression as attached to the person (e.g., *this person chooses this object because she likes it better*), whereas the latter account considers it rather as a feature of the object (e.g., *this person chooses this object because this object is better*). Hence, the object-centered approach implies more general usability of the information in a wide variety of situations, and allows universal behavioral predictions regardless of the person involved. In line with these assumptions, Gergely et al. (2007) reported that in a violation-of-expectation study with 14-month-olds ostensive signals could induce an object-centered interpretation of the referential emotion displays of others in infants.

The possibility of encoding such a choice event in a person-independent way was raised by the results of Moore (1999, Experiment 2). He presented 12-month-old infants with habituation events, involving agents who attended to objects. Infants saw a person looking at and pointing to one of two toys. Following habituation to one event, they were shown new-object and new-side test events. Infants who saw the same agent throughout the procedure looked longer on new-object than new-side trials, replicating the results of Woodward (1998). Importantly, infants who saw one agent in habituation and a new agent in the test also showed exactly the same pattern of response. Moore argued that infants in this case did not represent the event in terms of intentional relation between the particular agent and the toy.

On the other hand, others (Buresh & Woodward, 2007; Henderson & Woodward, 2012) tested the same phenomenon with a paradigm that involved the original situation of reaching for objects. Their results suggested that infants track action goals over time by linking them to the individual person who performs them: even 9-month-olds were able to mark goals as attributes of individual people. However, the paradigms of Buresh and Woodward (2007), and also that of Henderson and Woodward (2012) share an important feature. After habituation, in the test phase where the new actor appears and the position of the objects is switched, the actor uttered the following questions: "Hi, where is it? Did they switch? Where did it go?". We assume that this utterance invites a pragmatic supposition that the objectthe agent is looking for is not present in the scenario, which makes the 'new person' situation ambiguous, and this ambiguity might account for null results in their switch-actor condition.

The aim of the present study was to test whether 10-month-old infants would encode knowledge conveyed in a social situation as person-specific, or if these situations trigger the acquisition of more general knowledge (in a non person-specific way). We wanted to see whether infants who see an agent expressing his or her attitude towards an object would expect a newly introduced agent to have the same attitude.

Following Luo (2011), we showed infants a scenario in which Agent A expressed a particular attitude (that is, a preferential choice) towards an object. We introduced the scenario with two objects present. In the next step we manipulated the perspectives of the infant and the agent such that the infant, but not the agent, saw that one of the two objects had been removed. After this the agent approached the remaining object. Therefore, in the eyes of the infants, the agent did not make a preferential choice (given the role of contrastive choice mentioned earlier), but according to the agent's knowledge two objects were present when the choice was made. In order for infants to interpret the situation as an expression of preference, they had to view the action from the agent's perspective; moreover, they had to take into account the agent's (false) belief based on what the agent previously perceived (namely, notwitnessing the removal of the object). In the test phase we introduced a new agent (Agent B), who once chose consistently with Agent A, once inconsistently. To test the range of agents that the acquired knowledge could be applied to, we varied whether Agent B was an adult or a 2-year-old child.

Our crucial condition is the False Belief condition, where the agent falsely believes that there are two objects and hence she believes she is making a real choice. We argued that this condition would be the strongest test of the person-specific encoding. In this case infants attribute a preference to the agent, and this preference attribution is based on the preceding belief attribution. Since there are two mental state attributions taking place, this could allow for an even stronger person-specific encoding.

Our hypothesis was that infants would not encode inferred information as person-specific facts; rather they would apply it in a general manner to the object and attribute a selective preference to other agents as well.

2. Study 1: Method

2.1. Participants

A total of 81 infants were recruited through newspaper advertisement. Of these, 15 infants were excluded due to technical errors (8), or crying or fussiness (7). The final sample consisted of 66 infants, with mean age of $M = 307$ days ($SD = 11$ days), 37 boys and 29 girls. Infants were accompanied by their parents, who gave their informed consent for participating in the study and received a toy as a "thank-you" gift.

2.2. Stimuli

Each infant was shown a series of videos presented in PsyScope. After a 10-s attention grabber, a series of 7 videos were shown (see Fig. 1), with the following structure. Five sequences were as part of the orientation trials[1] – (1)

[1] These video sequences in the orientation trials were similar to the orientation events of Luo (2011) with the following modifications. In the script of Luo, the agent herself put one of the objects behind an opaque (or transparent) screen, and then while she was away, a hand withdrew the object form behind the screen. So when the agent returned she could (in case of the transparent screen) or could not see (in case of the opaque occluder) that the second object disappeared. We wanted to make sure that infants follow that the agent could not be responsible for the withdrawal of the object (which would be a possible perceived solution in Luo's scenario). Therefore, in our version first the model saw that two objects were behind transparent screens, and then an opaque occluder was lowered and blocked the visual access of the protagonist for one of the objects. So, during the withdrawal of the second object,which was the next step in the orientation trials, the model was visible with her two hands resting in front of her. We added this modification because this would allow even more information for infants to encode the belief formed by the agent person-specifically, as she is constantly part of the scene.

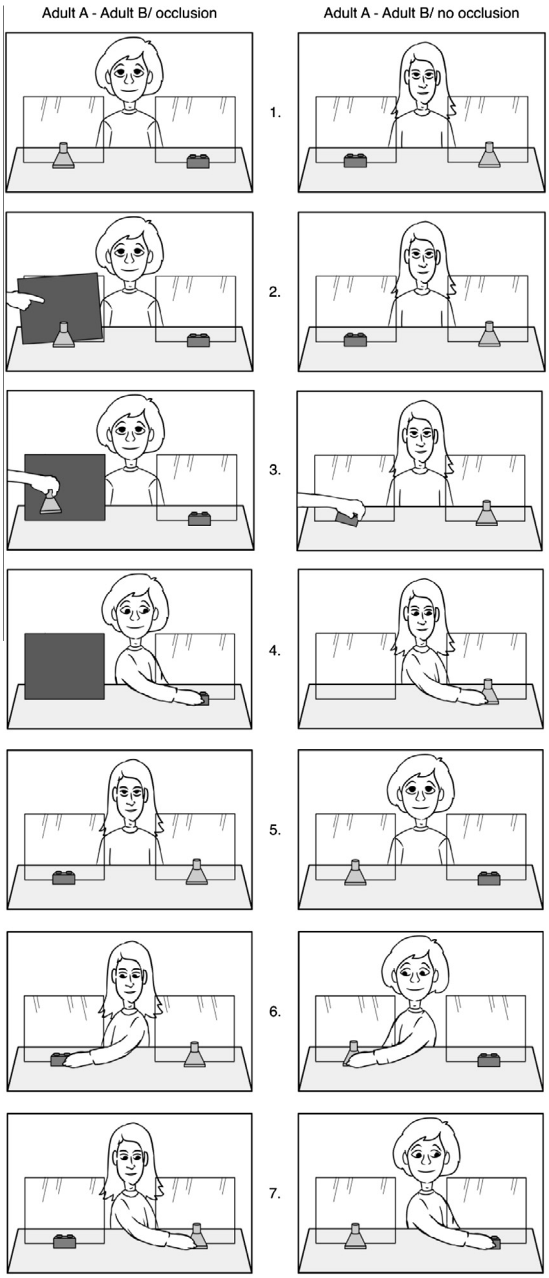

Fig. 1. Schematic drawings of the events during orientation and test trials in the Adult–Adult/occlusion, and the Adult–Adult/no occlusion (control) conditions. (1) Familiarization with Agent A, two objects visible, (2) occlusion of one object (only in the occlusion condition), (3) a hand, not visible to the Agent, reaches in and removes object A (this step being visible to the Agent only in no occlusion condition, but visible to the infant in all conditions), (4) Agent A grasps object B, (5) familiarization with Agent B, with both objects present again, and the locations switched, (6 and 7) Agent B grasps object A and object B (order of target object counterbalanced across infants). Adult–Child/occlusion condition was identical to Adult–Adult/occlusion condition, with the modification that Agent B was a 2-year-old child who performed the same acts as adult Agent B.

familiarization with Agent A, with two objects visible to both the infant and the agent, (2) occlusion of Object A (only in the occlusion conditions) from the agent but not the infant, (3) removal of Object A (this step being always visible to the infant, not visible to the agent in the Adult A–Adult B/occlusion and Adult A–Child B/occlusion conditions, but visible also for the agent in the Adult A–Adult B/no occlusion), (4) Agent A touches Object B (without Object A being present), (5) familiarization with Agent B, with both objects present but the object locations switched. Further two sequences were part of the test trials: (6) Agent B touches Object B (consistent choice), (7) Agent B touches Object A (inconsistent choice). The presentation of test events 6 and 7 were counterbalanced across subjects in each condition. At the beginning of each video (0.5 s before the onset), ashort sound was played to direct the infant's attention to the screen.

2.3. Materials

In the videos, Agent A sat behind a table and was visible from the waist up. The objects used in the videos were a $6 \times 6 \times 4$ cm yellow cuboid and a $6 \times 6 \times 6$ cm green pyramid with a 2 cm peak on the top. In the first setting, the two objects were placed behind two transparent screens, allowing both objects to be visible to the agent. In the occlusion conditions one object was occluded by a red cardboard placed next to the transparent screen, creating one single opaque screen between the agent and the object. During removal, a hand reached behind the screen and removed the object from the scene. This step was invisible to Agent A in the occlusion conditions but visible in the no-occlusion (control) condition. During the test phase the location of the objects was switched,and another agent (Agent B) was introduced. In the two test videos both objects were in front of Agent B, both behind a transparent screen and therefore visible for both the agent and the infant.

2.4. Design

A between-participants design was used, with the condition as the independent variable. Participants were randomly assigned to one of three conditions: (1) Adult A–Adult B/occlusion (23 infants), (2) Adult A–Child B[2]/occlusion (22 infants), or (3) Adult A–Adult B/no occlusion control group (21 infants). In Adult A–Adult B/occlusion condition both agents were adults, and the agent during familiarization did not see the removal of object A, due to the occluder placed between them and the object. In Adult A–Child B/occlusion condition the same setting was used, however, the second agent introduced in the 5th step was a 2-year old child. As a consequence, in these two conditions the agent made a false choice in the end of the orientation sequences (since the agent was not aware of not making a real choice due to the lack of the second object). In the third, Adult A–Adult B/no occlusion (control) condition object A was visible to the agent during all the orientation videos, therefore making it possible for agent A to observe the removal of the object.

[2] We use the letters A and B to refer to the first and second agent introduced (therefore "Child B" refers to the second agent being a child.

2.5. Procedure

Each infant sat on the lap of his or her parent, approximately 50 cm from the monitor. Two cameras were set so the experimenter could see online both the infant and the videos presented to him/her, and a split screen recording was created for offline coding. Videos 1–4 were approximately 15 s long and were presented consecutively to orient the infant. Video 5 was a familiarization trial with the objects' location switched, and the new agent (without action). During the test phase (after Videos 6 and 7) the screen froze and showed the last frame of the video until the infant looked away continuously for 2 s.

Recordings were then coded offline and looking times for inconsistent (IC) and consistent (C) videos were analyzed with a looking time program. A second observer coded 60% of the recordings. Inter-observer agreement was high ($r = 0.837$, $p = 0.01$).

2.6. Pretest

To test whether there were saliency differences between the two objects, the fixation patterns for the two objects used in the videos were measured using an eye-tracker (Tobii X50). Ten infants who were not part of the subsequent experiments (3 boys, 7 girls, mean age 309 days) were presented two pictures containing both objects in Clearview 2.5.1 (in the second picture the locations were switched) and fixation times were measured. A 2×2 repeated measures ANOVA with Identity of object (green cube vs. yellow pyramid) and Side (left vs. right) as factors showed no significant differences between fixation times to the two objects. There was no main effect of either Identity of object ($F(1,9) = 2.704$, $p = 0.135$), or Side ($F(1,9) = 2.861$, $p = 0.125$), and there was no significant interaction ($F(1,9) = 0.922$, $p = 0.362$). The result of this pretest proved that there were no baseline preferences with respect to the objects used in the video stimuli.

3. Study 1: Results

We conducted a repeated measures ANOVA in each condition (see Fig. 2), with Event (Consistent vs. Inconsistent) as a factor and Order (Inconsistent first vs. Consistent first) as a grouping variable. Preliminary tests showed no effect of sex, therefore this variable was omitted from further analyses in all three conditions.

In the case of the Adult A–Adult B/occlusion condition, the analysis revealed significant main effect of Event ($F(1,21) = 7.03$, $p = 0.015$, $\eta^2 = 0.251$), showing that infants looked significantly longer during inconsistent than during consistent events.

In the case of the Adult A–Child B/occlusion condition, the analysis revealed again a significant main effect of Event ($F(1,20) = 7.511$, $p = 0.013$, $\eta^2 = 0.273$), with longer looking times during inconsistent events. There was no main effect of Order, and no Order x Event interaction in either of the experimental conditions (Adult A–Adult B/occlusion condition and Adult A–Child B/occlusion condition).

In both the Adult A–Adult B/occlusion condition and the Adult A–Child B/occlusion condition infants looked longer at Inconsistent (IC) events than at Consistent (C) events. (Mean looking times in Adult A–Adult B condition: $M_{IC} = 14.89$ s, $SD = 10.01$; $M_C = 11.14$ s, $SD = 6.6$; in Adult A–Child B condition: $M_{IC} = 15.58$ s, $SD = 9.96$; $M_{IC} = 11.29$ s,$SD = 6.52$).

In the Adult A–Adult B/no occlusion control condition there was no main effect of Event ($F(1,17) = 0.001$, $p = 0.977$), suggesting that looking times between Consistent and Inconsistent events did not differ significantly. Again, there was no main effect of Order and no Event x Order interaction. In this control (Adult A–Adult B/no occlusion) condition, looking times between the two types of test events were similar ($M_{IC} = 9.53$ s, $SD = 6.34$; $M_C = 9.43$ s, $SD = 5.72$).

A mixed type ANOVA with Condition Type (Test vs. Control) as between-subjects factor and Event (Consistent vs. Inconsistent) as within-subjects factor yielded a significant main effect of Event ($F(1,64) = 6.187$; $p = 0.015$, $\eta^2 = 0.088$) and a significant Event x Condition Type interaction ($F(1,64) = 5.601$; $p = 0.021$, $\eta^2 = 0.08$). These results confirm that infants looked longer at the inconsistent choice events only in the test conditions but not in the control condition.

4. Study 2

Despite the remarkable perceptual difference between the two agents (especially in the Adult A–Child B condition), it is still possible that the infants cannot perceptually distinguish between them. To exclude the possibility that infants expected an identical choice from Agent B because they could not distinguish her from Agent A, we conducted a control study.

4.1. Participants

We tested fourteen 10-month-old infants, 10 of whom contributed to the final sample, and 4 were excluded due to crying (3) or technical error (1). Mean age was 300 days (SD = 9 days), 5 boys. Infants were accompanied by their parents, who gave their informed consent for participating in the study and received no financial reward but a symbolic toy for participation.

4.2. Materials

We used a similar procedure as Buresh and Woodward (2007), who tested whether 13-month-olds could discriminate the two agents in their studies. In order to guarantee that infants in this control experiment had the same amount of exposure to Agent A as in the other conditions, we used the same familiarization videos (steps 1–4) as in our occlusion conditions of Study 1, that ended in Agent A choosing one of the objects in step 4. After this, the location of the objects remained identical, but the previously removed object was present again (as in the original test phase), and two test events followed. In one condition the same agent (Agent A) remained, but wearing a different

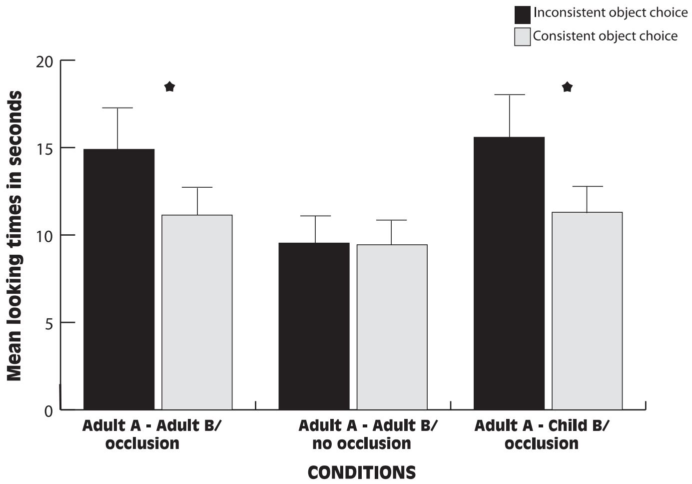

Fig. 2. Mean looking times of infants in the three conditions. Error bars represent standard errors. An asterisk (*) denotes $p < .05$.

shirt, and chose again the same object as in familiarization phase. In the other condition Agent B was present during test phase, and similarly to Agent A, chose the same object (with the location of objects still being constant). Infants sawboth test events in a within-subjects design, and we hypothesized that longer looking times to the test event with Agent B reflects novelty preference towards Agent B.

Since Agent A was wearing different clothing during the test phase than during the familiarization phase, if infants noticed the difference it could not have been merely due to noticing the different outfit of the actors. Moreover, the choice performed was identical across the familiarization and the two test videos. Hence, the only essential difference between them was the identity of the agent.

We used the Adult A–Adult B agent-pair because we argue that this is the harder discrimination to make; if infants can distinguish one female adult from another female adult, they must be able to distinguish between an adult female and a 2-year-old boy.

4.3. Procedure

The procedure was identical to Study 1. After testing, videos were coded offline and looking times for Same Agent and New Agent test videos were analyzed with a looking time program.

4.4. Results

We conducted a repeated measures ANOVA, with Agent (New Agent vs. Same Agent) as a factor and Order (Same Agent first vs. New Agent first) as a grouping variable. Preliminary tests showed no effect of sex, therefore this variable was omitted from further analyses.

The analysis revealed significant main effect of Agent ($F(1,8) = 6.264$; $p = 0.037$, $\eta^2 = 0.439$), showing that infants looked significantly longer during New Agent ($M_{NA} = 18.42$, $SD = 8.77$), than during Same Agent ($M_{SA} = 13.11$ s, $SD = 7.2$) videos. There was no effect of Order, and no Agent × Order interaction.

Thus, the looking time patterns revealed a novelty preference for Agent B, suggesting that infants were able to distinguish between the two agents.

5. Discussion

The goal of the present study was to investigate whether infants can bind the content of encoded mental states of a social partner to the respective person. Our results suggest that 10-month old infants can use the perceptual and knowledge states of others, without necessarily tracking which agent has a specific knowledge. Hence infants do not interpret the inferred preferential choice of an agent as related to that person; rather, they seem to infer that the content of the preferential choice could also be appropriate for other agents. Thus belief computation and preference attribution can be used not only to learn *about others* but also to learn *about the world* through the lenses of others, in the sense that they might learn about the object.

Our data suggest that infants could follow whether an agent does or does not have visual access to a scenario (e.g., not seeing that one of the objects was removed), and could also infer the agent's belief based on this visual access. Thus, they have also computed the agent's preference as a function of this (false) belief. Infants attributed preferential choice only when the agent has initially seen two objects in the scenario, but then did not see the removal of one of the objects, and thus infants have also computed the belief of the agent of two objects being present as a source of action prediction. Hence, the present results confirm those of Luo (2011, and also Luo & Baillargeon, 2005; Luo & Baillargeon, 2007) in the sense that for infants the availability of contrastive choice is crucial for inferring preference.

Moreover, these results confirm that infants can rely on the perspectives and knowledge of other agents to set up the preconditions for preference inferences. When attributing choice, infants did not rely on their own visual access to the scenario; rather, they took into account the agent's conflicting perspective and epistemic state – whether according to the agent's knowledge there are two objects or one – which was the reverse of what the infants could themselves see. It can be thus said that the results of the present paradigm speak for a mental state attribution that is functionally similar to belief attribution in adults. Proper belief attribution is characterized by Rakoczy (2012) as being inferentially connected to other mental states in order to guide rational action selection. In our case infants do, in fact, have to integrate the attributed beliefs with the preference in order to interpret the agent'sactions and have expectations regarding her (or another agent's) behavior.[3]

Our results show, nevertheless, that infants use the knowledge of another agent to predict not only the actions of this agent exclusively, but also the actions of other agents. Hence, the present results question the early availability of person-specific preference attributions, and refine the interpretation of early mindreading competencies of infants proposed by Luo (2011). Luo has found that 10-month-old infants interpret a person's choice of toys based on her true or false beliefs about which toys were present. According to her interpretation, these results indicate that *like adults*, even preverbal infants can consider others' mental states when making inferences about their actions. This would suggest that infants encode the attributed mental states as belonging to that specific person only. On the contrary, results of the present study showed that infants did not handle the emergentinformation based on someone's visual access in a person-specific way. They have used the acquired information to predict the actions of other agents accordingly.

Our pattern of results is in line with the findings of Moore (1999). He found that after habituating infants to an agent pointing to one of two objects, infants expected another agent as well to point to the same object. On the contrary, Buresh and Woodward (2007) found that infants did not expect a new person to approach the same object that the previous person did.

A possible explanation for the different findings could be that because the two agents, both in the Moore (1999) study and in the Adult A–Adult B/occlusion condition in the present study, were similar in appearance, infants may not have noticed the agent switch (whereas in the Buresh and Woodward study the gender difference between the two actors was salient). Study 2 addressed this issue and confirmed that infants at 10 months of age are able to perceptually distinguish between the two agents. In this study we tested whether they have a novelty preference to the new agent performing the same choice. According to our results infants can in fact discriminate between the two agents, therefore this factor cannot explain the results obtained.

In summary, based on the findings of the present study, we suggest that 10-month-olds can compute the visual access of others and attribute (true and false) beliefs accordingly. Furthermore, infants can use the inferred mental states in their evaluation and prediction of forthcoming actions and their outcomes. However, it is possible that infants are unable to integrate the information of the *source* of the mental states with their *content*. A possible interpretation of this interesting pattern of results is that infants are not yet able to track and relate the mental states of others in a person-specific manner.

We do not wish to imply that there can be attribution of propositional attitudes without an agent. Preference attribution requires an agent to be present in order for the preference attribution to be triggered. As such, an agent *is* necessary for mental state attribution. However, the question is whether infants in this case store this relation (this is what we refer to as binding), or it can be substituted by an 'agent–placeholder'. We argue that early on infants do not take into account that the attributed mental state was bound to a unique person.

This difficulty in information binding may also have an advantage for young infants. We suggest that infants can use content information they derive from the belief ascription to the social partner. Without source differentiation the content becomes part of a shared knowledge base that is applicable to other agents as well. An object that was chosen by one person can be categorized as a preferable/good object – a piece of information that can be generalized as relevant to conspecifics. Gergely, Egyed, and Király (2007) also proposed such an object-centered approach as an action interpretation strategy available for infants at the age of 14 months. Additionally, Egyed et al. (2013) found that 18-month-olds could switch between the object-centered and person-specific interpretations in a preference attribution paradigm. As such, it is plausiblethat young infants, since they cannot store and retrieve person-specific source information, can use an object-centered approach early in life to gather a universally shared knowledge base. Thus, the potential advantage of this early, but limited competence (i.e., the lack of binding of mental states to agents) is that it can support the recognition of generally preferred objects as common goals, and as such it could serve an important role in promoting joint action and cooperation.

Our study taps onto the hotly debated question whether infants possess full-blown Theory of Mind abilities. Some recent approaches argue that infants are only capable to attribute 'belief-like' informational states (see Apperly & Butterfill, 2009) or 'subdoxastic' states (Rakoczy, 2012), rather than 'proper beliefs'. In our view the beliefs (and other mental states) attributed by infants might not call for a different terminology that distinguishes them from proper beliefs (c.f. Onishi & Baillargeon, 2005; Surian et al., 2007). We claim that belief attribution observed in infants differs from adult-like ToM abilities, but these could be seen as points on a continuum rather than discrete categories. The main goal of our current study is to focus on the mechanisms of mental state ascription,rather on the terminological distinctions between proper beliefs and belief-like (or subdoxastic) states. The mechanism of mental state attribution has various features that can be subject of change during the lifespan. We suggest that

[3] Since looking time studies by their nature don't allow for testing the further criteria of 'proper beliefs' proposed by Rakoczy (2012) (whether the formed beliefs are accessible to consciousness, or inferentially promiscuous), we cannot come to a firm conclusion regarding the exact nature of the beliefs attributed by the infants.

one of these is the binding the belief contents with the owner of the belief.

A possible developmental trajectory of theory of mind abilities could be understood in light of the potential binding of mental states to the corresponding agent. Specifically, we propose that such person-specific belief encoding may emerge after the end of the first year of life, and then will become dominant strategy. Our results show that 10-month-olds possibly lack this ability, and results of Kovács et al. (2012) are in line with this pattern. In a follow-up study of Kovács et al. (2010), Kovács et al. (2012) found that even 14-month-old infants had difficulty tracking the agent that a belief belongs to, and were only able to do so if the agents were named in the beginning of the experiment. This, together with the results of Gergely, Egyed, and Király (2007), suggests that around 13–14 months under certain circumstances infants are ableto bind the mental state contents to the corresponding agents, but it still might not be the dominant stance. Later on, during the second year of life, both strategies are available in parallel, as suggested by Egyed et al. (2013). Our interpretation of their view is that object-centered information encoding arises as a result of the lack of mental state binding in the first year of life. Later on this process – that is, transmitting information generalisable across agents – is still available, but it is mostly triggered by specific cues, like ostensive, communicative signals. After the second year of life, the person-specific belief encoding can become more prominent, possibly resulting in processes similar to the full-blown Theory of Mind abilities. Promising evidence comes from studies using tasks in which children make active choices based on situative inferences (in situations involving communication, Southgate et al., 2010;active helping, Buttelman et al., 2009, and helping and correction with communicative pointing, Knudsen & Liszkowski, 2011; Knudsen & Liszkowski, 2012) – this in fact can reflect that children's belief attribution is more flexible and can guide their control of action.

Note that our results cannot be due to perceptual differences in the test events. Namely, that switching agents would be distracting or overwhelming for the infants. While in the Inconsistent choice trials, infants saw events with at least two salient differences between familiarization and test (new model grasping another toy), in the Consistent choice trials, there was only one salient difference (the new model grasping old toy). This difference in itself could result in a similar pattern of looking behavior. However, based on the above-mentioned perceptual difference, the predicted looking behavior of the Adult A–Adult B/no occlusion (control) condition would be similar to the two occlusion conditions, as in this regard they have the same structure of events. Since the results in this (control) condition differed significantly from the other two conditions, the perceptual differences cannot be responsible for the obtained data pattern.

Furthermore, this pattern of results cannot be explained merely by the combination of screens in the different condition. First, in her study Luo (2011) ruled out the possibility that infants' attribution of preference to the agent in one, but not in the other condition (shown by difference in pattern of looking times) could be merely the result of the different occluders in the two conditions. In Study 2 of Luo (2011) the agent either (a) falsely believed that there was only one object or (b) had a true belief that there were two. Results showed that infants' attribution of preference depended on the agent's knowledge about the objects and not the particular arrangements of occluders in the scene. Second, if in the present study merely the combination of screens (one transparent and one opaque screen) would determine looking times in the test events of FalseBelief condition (e.g., in the consistent choice test event), in Study 2 we should not have observed different looking times in the two test events (since both are preceded with familiarization including one transparent and one opaque screen, and both include consistent choice in test phase).

In sum, the main objective of the present study was to test whether infants understand preferential choice and others' perspective as a person-specific disposition in their action interpretations. We found that after a preference demonstration, where infants had to compute the preference based on someone's false belief, infants predicted the same object choice for a new agent. This finding leads to the proposal that there is a graspable gap between the early understanding of mental states and full-blown theory of mind capacities. Early competencies comprise (a) the capability to infer another person's belief upon this person's visual access to a situation and (b) the ability to use previously inferred mental representations for action prediction. Other studies that claimed to reveal early Theory of Mind competencies could also be interpreted in light of these two aspects of ToM (see Kovács et al., 2010; Onishi& Baillargeon, 2005; Surian et al., 2007; and Luo, 2011). Thus, what young infants may lack is the binding of the content of mental states to the person from whom that specific content was learned – a critical component for a person-specific mental state representation and action prediction system.

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