British Journal of Developmental Psychology (2007), 25, 461–470

The British Psychological Society

www.bpsjournals.co.uk

Infants' knowledge of the path that animals take to reach a goal

David H. Rakison[1]*, Jessica B. Cicchino[1] and Erin R. Hahn[2]
[1]Carnegie Mellon University, Pittsburgh, PA, USA
[2]Furman University, Greenville, SC, USA

Two experiments with the inductive generalization procedure tested whether 16- and 20-month-old infants understand that animals and not vehicles follow a rational path to reach a goal. Infants were tested with four different events and the model exemplar was either an animal or ambiguous block. Results showed that infants at 20 months of age, but not those at 16 months of age, understand that animals follow rational paths to reach a goal. However, 20-month-olds require the presence of static perceptual cues to apply a teleological interpretation to animals' actions.

Understanding that various object kinds engage in goal-directed action – that is, that animates purposely perform actions that have causal consequences – is a crucial first step in developing an awareness that things in the world possess psychological states. Relatively little is known, however, about when and how infants learn about the identity of things that move towards goals and the paths those things take to reach their goals. The aim of the experiments in this article was to examine this issue by focusing on infants' inductive generalization of goal-directed motion trajectories.

Gergely, Csibra and colleagues performed one of the first series of studies that addressed infants' understanding of the path that objects follow to a goal (Csibra, Gergely, Biro, Koos, & Brockbank, 1999; Gergely, Nádasdy, Csibra, & Biro, 1995). Gergely *et al.* (1995) and Csibra *et al.* (1999) habituated 9- and 12-month-olds to a visual event in which a small ball jumped over an obstacle to reach a large ball. A control group was habituated to the same event except that the obstacle was absent. The jumping action in the experimental environment was rational and goal-directed – it was necessary to move over the obstacle to reach the larger ball – whereas the same action in the control environment was not. Infants in both groups viewed two test trials; in one, the smaller ball jumped in the absence of the obstacle and in the other, the smaller ball moved in a straight line along the ground to reach the larger ball (also without the obstacle). Infants in the experimental condition recovered visual attention

*Correspondence should be addressed to David H. Rakison, Department of Psychology, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213 USA (e-mail: rakison@andrew.cmu.edu).

DOI:10.1348/026151006X171893

more to the non-rational jumping action than to the rational straight moving action, whereas infants in the control condition responded equally to the two events. Moreover, follow-up experiments revealed that 9- and 12-month-olds behaved similarly when indicators of animacy such as self-propulsion were absent (Csibra *et al.*, 1999), when the event involved a chasing event (Csibra, Biro, Koos, & Gergely, 2003), and when people rather than geometric shapes were the stimuli (Sodian, Schoeppner, & Metz, 2004).

Gergely *et al.* theorized that by 12 months of age infants apply a *teleological stance* or a *naïve theory of rational action* to interpret goal-directed events. This teleological stance causes infants to perceive an action as rational if it is explainable with reference to a future goal and if the path followed to achieve the goal is the most justifiable one available. That infants behaved similarly in the absence of dynamic animacy cues was interpreted to mean that such cues are neither sufficient nor necessary for a teleological interpretation of an object's behaviour (Csibra *et al.*, 1999).

Although the studies by Gergely *et al.* and Sodian *et al.* (2004) reveal putatively that young infants develop expectations that geometric objects and people follow rational paths to a target, an important question that remains untested is when and how infants learn that animates – namely, animals – follow such paths to a goal. The account presented by Gergely, Csibra and colleagues does not specify the mechanism by which infants learn that animals follow a rational path to a goal, though a corollary of their general view is that this knowledge develops around 12 months of age. It has also not been established whether such knowledge about animates is embedded in perceptual cues (e.g. legs, eyes) or based on the presence of motion alone (as Gergely, Csibra and colleagues suggest). Finally, all the studies to date that examined infants' understanding of the path that objects follow to a goal employed the habituation paradigm and it remains to be seen whether the same pattern of behaviour would be found in other infant-oriented paradigms that do not rely on looking time as the primary dependent measure.

The two experiments presented here were designed to address these issues. We propose that infants' knowledge of the path that animals follow towards a goal relies on learning associations between perceptual cues (e.g. animal shape, legs, eyes) and goal-directed and rational motion (see Rakison, 2003, 2005, 2006) and not through the application of a teleological stance as suggested by Gergely, Csibra and colleagues. Learning via such a general mechanism is generally thought to be slower than that via a specialized mechanism – such as that posited by Csibra *et al.* (1999) – and consequently we expected infants' knowledge of the paths than animals use to reach a goal to develop relatively late in the second year of life. As a corollary of our theoretical view, and in contrast that of Gergely, Csibra and colleagues, we also predicted that infants would fail to generalize motion on a rational path in the absence of perceptual cues to animacy. The experiments use the *inductive generalization* or *generalized imitation* procedure in which infants observe an experimenter perform an action or motion and are then encouraged to demonstrate that action with two or more novel objects. This procedure has proved to be effective in evaluating older infants' knowledge of a variety of actions (e.g. drinking from a cup; Mandler & McDonough, 1996, 1998) and motions (e.g. non-linear land and air trajectories; Rakison, 2005) for animals and vehicles, and it allowed us to determine whether infants would demonstrate an understanding of the paths that objects follow to a goal in a more active paradigm than visual habituation that involved three-dimensional objects scale model objects.

EXPERIMENT 1

This experiment was designed to examine whether 16- and 20-month-olds generalize a goal-directed motion along a rational path to a novel animal rather than a novel vehicle. These age groups were tested because recent evidence suggested that it is around this period that infants begin to learn about the motion paths of animals and vehicles (Rakison, 2005). An experimenter modelled four events in-turn in which an animal moved towards a goal after which infants were encouraged to perform the goal-directed motion with an animal or vehicle in a new environment in which the original motion path was now non-rational and an alternative rational path was available. We used vehicles as a contrasting category because they move but are not rational entities.

Method

Participants

Participants were 20 infants with a mean age of 16 months, 3 days (range = 15;17 to 16;17) and 20 infants with a mean age of 20 months, 10 days (range = 19;2 to 21;14). Six further infants were tested but not included in the final sample, four due to fussiness, one because of experimenter error and one because the parent interfered.

Stimuli

There were four distinct events in which an animal was moved by an experimenter towards a goal along a rational path. Two of the modelled motions were curvilinear and two were linear. In one curvilinear motion event, an animal jumped over an obstacle and in the other, an animal travelled over a hill. In one linear motion event, the animal moved across a bridge over a valley and in the other, the animal moved across a bridge over a gap. These paths are illustrated in Figure 1a. In the test phase, infants were presented with the same environment but with a key component missing. Thus, the obstacle and the hill were removed from the curvilinear events and the bridges were removed from the linear events. These test environments are presented in Figure 1b with the rational motion paths illustrated by solid lines and the non-rational motion paths by dotted lines.

The goal objects were food (obstacle), a ball (hill), a person (valley) and a shelter (gap). The model exemplars in the tasks were a dog, a goat, a horse and a rhinoceros. The animal and vehicle test pairs were a sheep and truck, a pig and car, a cat and RV, and a cow and motorcycle. Movable object parts (e.g. wheels) were glued to minimize any extraneous salience due to their movement.

Every event was accompanied by two vocalizations by the experimenter: 'Woosh' for the hill motion and 'let's go play' on reaching the ball; 'Weee' for the hill and 'Num Num' on reaching the food; 'Zoop' for the valley and 'Hello' on reaching the person; 'Tum' for the gap and 'Go inside' on reaching the shelter. The order in which the motions were modelled, the pairing of the test exemplars with the motion events and the location of the test exemplars in front of the infants were counterbalanced.

Procedure

Participants sat on their parent's lap across the table from the experimenter. Infants' behaviour with the test exemplars was evaluated before (baseline) and after

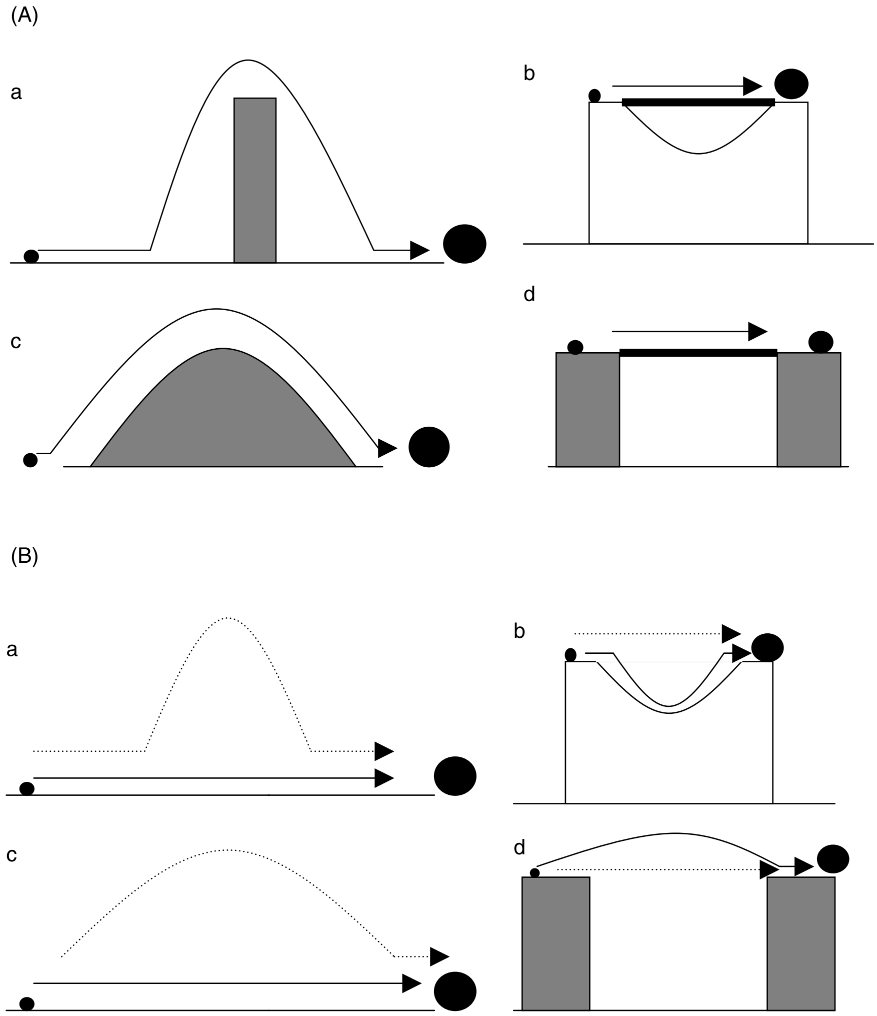

Figure 1. (A) Motion events modelled in Experiments 1 and 2. The small circle is the moving object and the large circle represents the goal. The motion paths modelled were (a) jumping over a block, (b) going across a bridge over a valley, (c) climbing over a hill and (d) going across a bridge over a gap. (B) Motion arenas in generalization phase of Experiments 1 and 2. Rational motion paths are illustrated by the solid line and the non-rational motion paths by the dotted line. Note that two of the rational and non-rational paths were linear and two of the rational and non-rational paths were non-linear.

(generalization) each motion event was modelled. During the baseline phase of each event, the infant was given two test exemplars and the test environment (see Figure 1b) and allowed to interact with them freely and with no prompting. Baseline exploration lasted approximately 45 seconds or until there was no further manipulation. The experimenter then removed the test environment and the stimuli and then reintroduced the modelling environment (see Figure 1a) with the appropriate model exemplar. The experimenter demonstrated the goal-directed motion with the model exemplar four times with the appropriate vocalizations. The direction of the event (e.g. moving left to right or right to left) was counterbalanced for each infant.

The experimenter then removed the modelling environment and the model exemplar. The testing environment and stimuli presented during baseline were then reintroduced. The experimenter prompted the infant to demonstrate an action by saying, for example, 'Can you show me [motion vocalization]?' and simultaneously moving one hand from the starting-point to the goal. The same vocalization was used in the testing phase as was presented in the modelling phase for that particular event. Care was taken not to repeat the motion path shown during the modelling phase; instead, the experimenter moved a hand in the general direction of the goal. Infants were allowed to respond in any way and no further prompting was given. The experimenter ended the generalization phase when infants ceased to interact with the stimuli or after approximately a minute. The session was videotaped for later analysis.

Scoring

Infants were coded for the path along which they moved an object to the goal and the exemplar used to make the response. Motions coded as 'rational' and 'non-rational' for each event type are illustrated in Figure 1b. A path was considered to be straight if the infant kept the exemplar at a constant height for the majority of the action towards the goal. In contrast, a curved path constantly increased or decreased in height at an angle of approximately 30 degrees or more. Coders viewed videotapes frame-by-frame to determine path type. Videos were recorded from a camera that was situated 168 cm away from and 91 cm above the infants. The camera was angled downwards and zoomed in so that infants' recorded actions filled the entire screen. Percentage reliability for objects touched and actions performed by the infants was 96%.

Results

In the two experiments presented here, infants rarely demonstrated motions during baseline, showed no consistent spontaneous preference for any particular event or any test stimulus during baseline, and without exception demonstrated more motions during generalization than baseline. This low level of behaviour during baseline is consistent with the previous studies with the generalized imitation procedure (e.g. Mandler & McDonough, 1996, 1998). Consequently, baseline analyses are excluded from the presentation of the results.

The primary measure of infants' behaviour in each task was the first object used to demonstrate a motion and the path (rational or non-rational) that the object was made to travel to the goal. Across the two experiments reported here, there were no consistent significant differences in infants' behaviour on the four different events; consequently, in Experiments 1 and 2, the data were collapsed across these events. The first test was conducted with a mixed-design analysis of variance (ANOVA) with path demonstrated by infants (rational vs. non-rational) and category (animal vs. vehicle) as the within-subject factors and by age (16 months vs. 20 months) as the between-subject factor. The dependent variable was the number of motion events (rational or non-rational) demonstrated by each participant with either the test animal or test vehicle (range = 0–4). To allow comparison across measures, age groups and tasks, all measures are reported in percentages.

The analysis revealed a main effect for category, $F(1, 38) = 15.63$, $p < .001$, with infants across the two age groups demonstrating motions more often with the animals ($M = 48\%$) than the vehicles ($M = 17\%$). There was also a significant interaction between the age of the infant and the motion path they demonstrated, $F(1, 38) = 5.37$, $p < .025$. These data are illustrated in Figure 2. Further analyses revealed that 16-month-olds were just as likely to demonstrate rational and non-rational paths to the goal, $F(1, 19) = 1.29$, $p > .2$, but 20-month-olds demonstrated significantly more rational than non-rational motions, $F(1, 19) = 4.41$, $p < .05$. Finally, there was a marginally significant interaction between age, path of motion and category, $F(1, 38) = 3.82$, $p < .06$. The interaction revealed that although both age groups were more likely to use the animal stimuli to enact the events, the 16-month-olds were just as likely to use the animals to perform rational as non-rational actions whereas the 20-month-olds were more likely to use the animals to perform rational than non-rational actions.

Discussion

The results of Experiment 1 suggest that infants at 16 months do not understand that animals follow rational paths to reach a goal whereas infants at 20 months do. The younger age group was more likely to demonstrate goal-directed motions with the animals than the vehicles but were just as likely to move them along rational as non-rational paths. In contrast, the older age group demonstrated goal-directed actions with animals and moved them along a rational path to reach the goal. Notably, infants in the two age groups performed an equivalent number of actions. Thus, any differences in behaviour cannot be attributed to a failure of the younger group to imitate the observed motions.

According to one view, dynamic or static animacy cues (e.g. self-propulsion, eyes) are neither sufficient nor necessary for infants to apply a teleological stance to the behaviour of an object (Csibra *et al.*, 1999). This view was tested in Experiment 2 with regard to static perceptual cues by presenting infants with the same events as those used in Experiment 1 but with ambiguous model exemplars. The use of such ambiguous models has proved successful in other inductive generalization tasks designed to test infants' knowledge of motion properties (Rakison, 2005); that is, infants at 18 and 22 months generalize linear and non-linear motion paths to real-world objects when those paths were modelled with an ambiguous object.

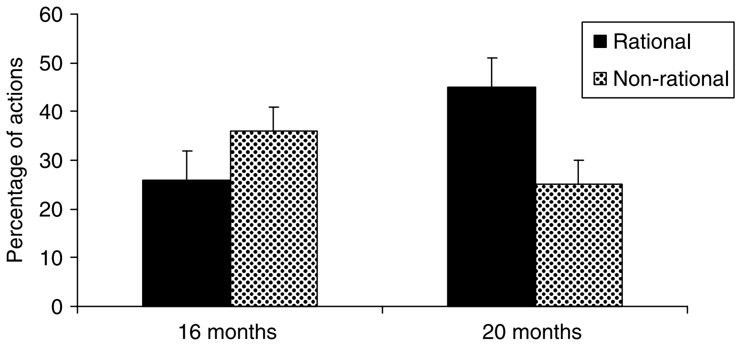

Figure 2. Percentage of rational and non-rational actions performed by 16- and 20-month-olds in Experiment 1.

EXPERIMENT 2

Method

Participants

Forty infants participated in this experiment. There were 20 infants with a mean age of 15 months, 24 days (range = 15;14 to 16;14) and 20 infants with a mean age of 20 months, 2 days (range = 19;14 to 20;14). Nine further infants excluded from the final sample, three because of fussiness, four because of experimenter error, one because of equipment failure and one because of parent interference.

Objects and properties tested

Infants' behaviour was assessed with the same events and stimuli as those in Experiment 1. However, the model exemplars were four distinct ambiguous objects (see Figure 3) made from clay and of different colours. The rationale for using these blocks was to minimize the information given to infants about the identity of goal-directed exemplars; performance in the task could only be based on prior knowledge about animals as rational, goal-directed entities.

Procedure, coding and scoring

The procedure and coding were identical to that employed in the first experiment. All tasks were videotaped and scored in the same format as in Experiment 1. Inter-rater reliability was 95%.

Results

The data from Experiment 2 are presented in Figure 4. A mixed-design ANOVA revealed no significant main effect of path demonstrated, $F(1, 38) = 1.66$, $p > .2$. Infants across the age groups were also just as likely to use the animals ($M = 45\%$) and vehicles ($M = 27\%$) to demonstrate the actions, $F(1, 38) = 0.06$, $p > .9$. The analysis also generated a main effect of age, $F(1, 38) = 16.43$, $p < .001$, which indicated that the 20-month-olds performed more actions overall ($M = 38\%$) than the 16-month-olds ($M = 22\%$).

Discussion

Experiment 2 showed that in the absence of perceptual cues of animals, infants at 16 and 20 months of age do not apply a teleological interpretation to goal-directed movement. In contrast to Experiment 1, infants at 20 months were just as likely to

Figure 3. Ambiguous blocks used as model exemplars in Experiment 2.

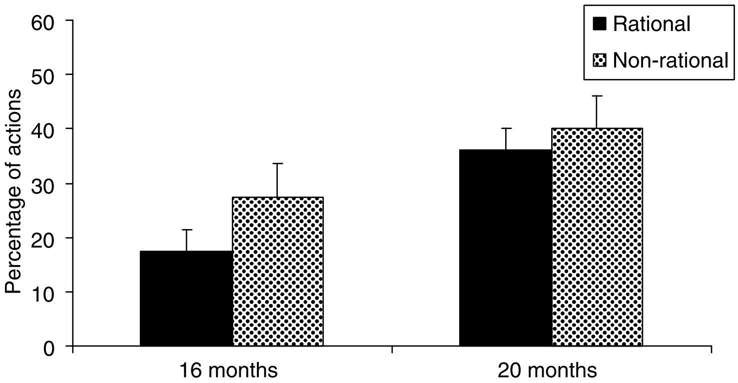

Figure 4. Percentage of rational and non-rational actions performed by 16- and 20-month-olds in Experiment 2.

demonstrate rational as non-rational motion paths and they were just as likely to demonstrate the observed motions with animals as vehicles. This suggests that infants at 16 and 20 months of age require the presence of certain, as yet unknown, surface perceptual cues to interpret an object's motion towards a goal as rational.

GENERAL DISCUSSION

The two experiments presented here suggest that infants at 20 months of age, but not those at 16 months of age, understand that when animals move towards a goal they follow a rational path. This finding is consistent with recent research on the acquisition of knowledge for animate motion properties in infancy. For instance, using the inductive generalization procedure, it has been shown that it is not until 18–22 months that infants learn that animals move non-linearly and vehicles move linearly (Rakison, 2005). In conjunction, these findings suggest that infants' ability to learn which object kinds engage in distinct motions may develop more gradually than previously theorized and that this knowledge, once established, is grounded in perceptual features of object rather than motion cues (Quinn & Eimas, 1997; Rakison, 2003; c.f., Mandler, 2003). It is unclear at this point why infants require static perceptual cues to interpret an action as rational, particularly given that they show no such limitation for other motions typical of animals or vehicles (Rakison, 2005). It is plausible that the associative link between rational action and specific object features (e.g. eyes, legs) is so strong that infants will not generalize it to novel objects that do not possess those features.

It remains to be seen whether the current data undermine or are complementary to those of Csibra *et al.* (1999) and Gergely *et al.* (1995). The findings reported here could be interpreted to contradict those of Csibra *et al.* (1999) in two ways. Recall that Csibra *et al.* found that 9- and 12-month-olds interpreted a ball's movement as rational and goal-directed and did so when indicators of animacy such as self-propulsion were absent. In contrast, infants at 16 months of age in the current experiments did not interpret teleologically the motions of the animals, and infants at 20 months of age failed to do so in the absence of static perceptual cues such as legs and eyes.

At the same time, it is possible that infants interpret teleologically certain motion trajectories – for example, jumping motions – and not others such as those we used in these experiments. It could also be argued that infants initially adopt a teleological stance and that the early representations for rational action are extended through more general mechanisms. Also feasible is that looking tasks and manipulation tasks tap different aspects of infants' representations: according to one view, looking tasks tap perceptual representations whereas manipulation tasks tap conceptual representations (Mandler, 2003). We do not subscribe to this view, however, and if anything it would suggest that infants tested in the inductive generalization paradigm should outperform those tested in the habituation paradigm. Finally, it could be argued that the tasks used here were more complex than those used by Gergely, Csibra and colleagues because they included animals and vehicles rather than geometric figures.

In our view, the present data support the notion that infants' knowledge about the path that animals follow towards a goal is not generated through the application of a teleological stance, as suggested by Gergely, Csibra and colleagues. The current data are consistent with the idea that domain-general mechanisms such as associative learning can account for how infants learn about the motion properties of animates and inanimates (see also Jones & Smith, 1993). We see no reason why infants would not learn about the path that objects follow to reach a goal in the same way that they learn about other motion properties; that is, by associating surface, perceptual cues (e.g. animal shape, legs, eyes) with specific trajectories of movement (see e.g. Rakison, 2005, 2006). Future research could address which cues are necessary or sufficient for infants to generalize motion along a rational path from a model exemplar to animals and people.

Acknowledgements

The authors thank Jaime Derringer, Juli Harrison, Marta Biarnes, Katherine Waite, Rachel Wu, Samantha Monda and Emily Sieg for their help in data collection and coding. Thanks also to two anonymous reviewers and the editor for constructive comments during the review process.

References

Csibra, G., Biro, S., Koos, O., & Gergely, G. (2003). One-year-old infants use teleological representations of actions productively. *Cognitive Science*, *27*, 111–133.

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

Jones, S. S., & Smith, L. B. (1993). The place of perception in children's concepts. *Cognitive Development*, *8*, 113–139.

Mandler, J. M. (2003). Conceptual categorization. In D. H. Rakison & L. M. Oakes (Eds.), *Early category and concept development: Making sense of the blooming, buzzing confusion* (pp. 103–131). New York: Oxford University Press.

Mandler, J. M., & McDonough, L. (1996). Drinking and driving don't mix: Inductive generalization in infancy. *Cognition*, *59*, 307–335.

Mandler, J. M., & McDonough, L. (1998). Studies in inductive inference in infancy. *Cognitive Psychology*, *37*, 60–96.

Quinn, P. C., & Eimas, P. D. (1997). A reexamination of the perceptual-to-conceptual shift in mental representations. *Review of General Psychology*, *1*, 271–287.

Rakison, D. H. (2003). Parts, motion, and the development of the animate-inanimate distinction in infancy. In D. H. Rakison & L. M. Oakes (Eds.), *Early category and concept development: Making sense of the blooming, buzzing confusion* (pp. 159–192). New York: Oxford University Press.

Rakison, D. H. (2005). Developing knowledge of motion properties in infancy. *Cognition*, *96*, 183–214.

Rakison, D. H. (2006). Make the first move: How infants learn the identity of self-propelled objects. *Developmental Psychology*, *42*, 900–912.

Sodian, B., Schoeppner, B., & Metz, U. (2004). Do infants apply the principle of rational action to human agents? *Infant Behavior and Development*, *27*, 31–41.

Received 28 June 2006; revised version received 16 November 2006