ARTICLE IN PRESS

Available online at www.sciencedirect.com

SCIENCE DIRECT

ELSEVIER

Cognitive Psychology xxx (2006) xxx–xxx

Cognitive Psychology

www.elsevier.com/locate/cogpsych

Will any doll do? 12-month-olds' reasoning about goal objects

Elizabet Spaepen [a,*], Elizabeth Spelke [b]

[a] *Department of Psychology, University of Chicago, 5848 S. University Ave., Chicago, IL 60637, USA*
[b] *Department of Psychology, Harvard University, 33 Kirkland St., Cambridge, MA 02138, USA*

Accepted 12 June 2006

Abstract

Infants as young as 5 months of age view familiar actions such as reaching as goal-directed (Woodward, 1998), but how do they construe the goal of an actor's reach? Six experiments investigated whether 12-month-old infants represent reaching actions as directed to a particular individual object, to a narrowly defined object category (e.g., an orange dump truck), or to a more broadly defined object category (e.g., any truck, vehicle, artifact, or inanimate object). The experiments provide evidence that infants are predisposed to represent reaching actions as directed to categories of objects at least as broad as the basic level, both when the objects represent artifacts (trucks) and when they represent people (dolls). Infants do not use either narrower category information or spatiotemporal information to specify goal objects. Because spatiotemporal information is central to infants' representations of inanimate object motions and interactions, the findings are discussed in relation to the development of object knowledge and action representations.

Keywords: Goal attribution; Categorization; Action representation; Object representation

1. Introduction

In order to make sense of any goal-directed action, one must represent and integrate information about the actor, the action itself, and the goal object. Although adults do this

* Corresponding author.
E-mail address: liesje@uchicago.edu (E. Spaepen).

0010-0285/$ - see front matter © 2006 Elsevier Inc. All rights reserved.
doi:10.1016/j.cogpsych.2006.06.001

with ease, the task is extremely difficult, because correct interpretations of goal-directed action depend in complex ways on the situation in which an action occurs. For example, consider the act of reaching for a toothbrush. When it is performed at a sink, we likely think that the actor aims to brush his teeth with that particular object: i.e., we endow the actor with agency, predict his future behavior (tooth brushing), and infer that the goal of his action was the individual bounded object in his hand: *his own* toothbrush rather than any of the others at the sink. When the same action is performed at a drug store, however, we likely infer that the actor aims to buy a toothbrush. In this case, his actions are predictive of a different future action (paying the cashier), and the goal of his action is understood to be not the individual package in his hand but the toothbrush inside, and that any of the toothbrushes of a given type would have been equally satisfactory goal objects. How do we perform these nuanced interpretations of goal-directed behavior? Adults' object and action representations are complex, integrated, and fine-tuned to myriad contextual cues indicating the level of specificity at which to interpret an intentional action and its goal. To understand the core properties upon which we build these action representations, however, we must study how infants, who have little or no experience with actions and goals, begin to understand the complexity of goal-directed behavior. How do infants construe the goals of other people, and how does their understanding change with experience?

Research on infants' representations of objects provides evidence for high sensitivity to the features of object categories that adults use to track and categorize them. In numerous habituation experiments, infants form categories of perceptually similar objects (Cohen & Younger, 1983; Eimas & Quinn, 1994; Quinn & Eimas, 1993). Given appropriate spatiotemporal information, infants as young as 2–4 months represent objects as numerically distinct individuals (Carey & Xu, 2001; Spelke, 1990). Experiments using object manipulation indicate that infants 9–11 months and beyond are sensitive to the complex collections of properties that specify global object categories such as animal, vehicle, and furniture (Mandler, 1992; McDonough & Mandler, 2000; Pauen, 2002). Infants sometimes use this property information to segregate objects with shared boundaries (Needham, 1998).

Considerable controversy surrounds research on the ability of infants to integrate property information to perceive individual objects as members of stably persisting kinds: cups, bears, and toothbrushes. Research by Xu and colleagues suggests that the ability to form representations of property and kind information to discriminate and individuate objects emerges at about 12 months of age, in studies requiring use of featural information to predict the number of objects behind an occluder (Xu & Carey, 1996), or to parse object boundaries (Xu, Carey, & Welch, 1999). Younger infants, who fail these tasks using only property or kind information, succeed in doing so when spatiotemporal information is provided (Xu & Carey, 1996). Both groups of infants show sensitivity to the property differences of these objects, yet the younger infants do not use either kind information or property information for object individuation.

Further studies suggest that 12-month-old infants use kind contrasts rather than property contrasts for object individuation. Xu, Carey, and Quint (2004) provide evidence that, although infants detected the property differences between two perceptually distinct objects of the same kind (a china coffee mug and a plastic, hooded sippy cup) they failed to use them to infer two objects behind the screen. The infants only expected two objects behind the stage when the objects differed in kind (Xu et al., 2004).

Wilcox and colleagues have shown similar failure to use featural properties to individuate objects in young infants up to 11.5 months old, though the age at which infants begin to succeed in these tasks depends on the type of task infants must solve and on the kind of featural cues to object identity that are available to them (Wilcox, 1999). More recent research suggests that younger infants can be primed to use property information to individuate objects when those features are first shown to have a functional value (Wilcox & Chapa, 2004).

All researchers agree, however, that spatiotemporal information is primary in object representations (e.g., Wilcox, Schweinle, & Chapa, 2003). Indeed, spatiotemporal information remains primary even for adults, where attentive tracking of individual objects depends on their spatiotemporal properties and not, in some situations, on the features that distinguish different object categories (Kahneman, Treisman, & Gibbs, 1992; Leslie, Xu, Tremoulet, & Scholl, 1998).

However, infants perform a very different task when they view a human agent act on an object, because they must determine the goal of the agent with respect to the objects in front of her. The task of specifying the object of a goal-directed action requires that one determine both the boundaries and the specificity of the goal object. Thus, infants must not only decide which part of the surrounding layout the actor seeks (the box she holds or the toothbrush inside), but also whether she seeks a particular object (as in the toothbrush-at-the-sink example) or a category of objects (as in the toothbrush-at-the-drugstore example). In the latter case, moreover, the infants must determine the nature of the object category.

When perceiving objects during goal-directed action, Woodward and her colleagues have shown that even very young infants can use feature and/or kind information to treat two goals from different global categories (a bear and a ball) as distinct (see Woodward, Sommerville, & Guajardo, 2001 for review). Woodward's research suggests that by 5 months of age, infants have a basic understanding of the goal-directed actions that they themselves can perform. In her seminal paper, Woodward (1998) showed 5- and 9-month-old infants two objects from different global categories on a stage and a hand that reached out and grasped one of the objects. After habituation to this event, the locations of the two objects were switched and the hand reached to each of the objects on alternating test trials. Both 5- and 9-month-old infants looked longer when the hand reached for the new object in the old location, suggesting that they understood the action not simply as motion in space but as directed toward an object (Woodward, 1998). Further experiments revealed that older infants distinguish intentional from accidental actions and represent only the former as goal-directed (Woodward, 1999; see also Johnson, Booth, & O'Hearn, 2001; Meltzoff, 1995), parse actions into units along intentional boundaries (Baldwin, Baird, Saylor, & Clark, 2001), interpret embedded actions as directed toward distant goals (Woodward & Guajardo, 2002; Woodward & Sommerville, 2000), and infer that distinct actors have distinct goals (Onishi, 2002). All of these findings show that systematic knowledge of agents and their actions develops during infancy. In each case in which the infants interpreted an action as goal-directed, they succeeded in interpreting two goals from different global object categories as distinct.

Woodward and her colleagues' findings suggest that infants interpret the actions of people and other agents as directed to kinds of objects at least as broad as the basic level, or perhaps to individual objects. On the other hand, previous research in object representation suggests that infants' attribution of goals will be directed first and foremost to individual bodies that are spatiotemporally cohesive and continuous. Because these two lines of research have yet to be fully integrated, however, many open questions remain regarding infants' representations of objects during goal-directed action. At what level of specificity do infants interpret others' goals? How do infants as young as 5 months treat two goals as distinct without the necessary spatiotemporal information to individuate them? Given spatiotemporal information during a goal task, how do infants integrate this into their attribution of goals? What are the core properties of objects that infants use to determine the goal of an action? Is spatiotemporal information primary to this process, as in object representation, or does featural information play a dominant role? The present experiments address these questions.

In six experiments, 12-month-old infants viewed a person who looked at and reached for one of the two objects. The first experiment replicated Woodward (1998) with two highly distinct goal objects—a toy truck and a doll—and showed that 12-month-old infants do indeed form expectations about the intentions of an actor's reach based on previous behavior. Then we investigated whether infants reason about that goal object as a specific individual, as a member of a narrowly defined category, or as a member of a global category of objects. In Experiment 2, we habituated infants to an agent reaching to one doll or truck and then tested them with reaches to a new doll or truck that differed from the first object in salient and potentially important ways (dolls differed in race and gender; trucks differed in their function) and were readily discriminated by infants (Experiment 3). Infants looked longer when the person directed her reach to the object from the novel category, providing evidence that gross featural information or gross category information influenced infants' representation of the goal object. Experiment 4 investigated whether infants could represent goal objects more narrowly, when they viewed a person reaching to one of the perceptually different trucks or dolls. Infants looked equally to the two similar goal objects, suggesting that more subtle featural information and narrower categorical distinctions did not influence infants' representations of the goal object. Finally, two experiments investigated the role of spatiotemporal information for individuation of goal objects. To our surprise, spatiotemporal information had no effect on infants' representation of the goal of the actor's reach. Together, these findings suggest global object categories, at least as broad as the basic level, guide infants' interpretations of the goal of intentional reaching and grasping actions. Infants' focus on global categories in interpreting human actions contrasts with their focus on spatiotemporal information in interpreting inanimate object motions and mechanical interactions.

2. Experiment 1

In the first experiment, we replicated Woodward (1998) with two highly distinctive objects: a doll and a truck. Twelve-month-old infants were familiarized to an event in which a person, who faced a toy truck and a doll, turned to and reached for one of the two objects. Then the positions of the objects were reversed and infants viewed, the person reaching for each of the objects in turn. Following Woodward (1998), we expected infants to look longer when the person reached to the new object at the old location than when she reached to the old object at the new location.

2.1. Method

2.1.1. Participants

Participants were 16 full-term 12-month-old infants-eight boys and eight girls-with a mean age of 11 months 30 days (range: 11 months 16 days to 12 months 10 days). One additional infant was tested but excluded due to fussiness.

2.1.2. Displays

Infants sat on a parent's lap facing a stage about 18 in. away. A doll and a truck sat on the stage, each on a pedestal 4.5 in. high and 10 in. apart. Four objects were used in total: a red metallic tow truck, an orange plastic dump truck, a white male doll, and a black female doll. The objects were chosen to be as perceptually different as possible while still belonging to the same basic-level category (i.e., truck and doll). Each infant either saw the white male doll and the red tow truck or the the black female doll and the orange dump truck. An actor, wearing a navy blue visor low enough on her face to ensure that she did not make eye contact with the infant, knelt behind the stage, visible to the infant from the waist up. She wore a turquoise t-shirt and no jewelry. Navy blue cloth behind the actor covered the back and the sides of the stage. A navy blue screen was lowered from behind the stage between trials, blocking the infant's view of the objects and the actor. Parents were instructed to close their eyes or to look at the infant during test trials.

2.1.3. Design

Half of the infants were familiarized with reaching to a truck and half were familiarized with reaching to a doll. Then all of the infants viewed six alternating test trials in which the person reached to the truck or the doll. The particular objects, their lateral positions, the order of the test trials, and the gender of the infant were counterbalanced across the subjects within each condition.

2.1.4. Procedure

Each habituation trial began when the screen was raised, revealing the actor and the two objects on stage. Her right hand rested on the stage until the baby was attending to the objects on stage, at which point she reached for one of the objects. Looking times were recorded starting when the actor's hand reached the object and stopped moving. The trial continued until 120 s had elapsed or the baby looked away for more than 2 s. Infants were considered habituated when looking times in three consecutive trials totaled less than half of that obtained in the first three trials, or when 14 trials had been completed. Infants who had not habituated after 14 trials were excluded from the study.

After habituation, the screen was lowered, and raised to reveal the two objects in their new locations with no actor present for one 15-s familiarization trial. Then, each infant saw six alternating test trials, in which the actor reached either to the new object at the old location or to the old object at the new location.

2.1.5. Data coding, analysis, and preliminary findings

The infant's looking was coded online by two observers who viewed the infant over separate video monitors in an adjacent, sound-isolated room. Both observers were blind to the condition to which the infant was assigned; they pressed button boxes when the baby looked at any part of the stage containing the objects or actor. Inter-observer agreement averaged 94% over all five experiments.

Looking times to each object during the familiarization trial were coded offline, and the proportion of time infants spent looking at the object that was the goal of the person's reach was calculated. A second coder also coded 25% of the trials for reliability, and agreement was over 90% for each trial.

Patterns of looking during habituation trials did not differ for the infants who viewed reaching to a doll versus a truck. Each experiment showed similar habituation averages

(8.4 trials in Experiment 1, 7.8 trials in Experiment 2, 7.6 trials in Experiment 4, 7.0 trials in Experiment 5, and 7.6 trials in Experiment 6). Similarly, infants habituated to a reach for a doll and those habituated to a reach for a truck habituated equally quickly (7.5 trials for doll reaches and 7.8 trials for truck reaches over all four experiments).

2.2. Results

Repeated measures ANOVAs revealed no main effects of gender, habituation object, object color (red truck/white doll or orange truck/black doll), direction of reach in habituation, or order of test trials, and no significant interaction between these variables. All further analyses were collapsed over these variables.

Fig. 1 summarizes infants' looking times to habituation and test trials for Experiment 1. A 2 (trial type) × 3 (trial pair) ANOVA revealed a main effect of type of test trial (new object or new location), $F_{(1,15)} = 23.101$, $p < .0001$, a main effect of trial pair (first pair of test trials, second, and third), $F_{(1,15)} = 6.100$, $p < .05$, and a significant interaction between the two factors, $F_{(1,15)} = 11.618$, $p < .01$. Infants looked longer when the actor reached for the new object using the same path of motion as during habituation, especially on the first trial pair.

A one-sample *t*-test of proportion of looking at the target object during the familiarization revealed that infants spent equal amounts of time looking at the objects, $t(12) = .183$, $p = .858$, suggesting that the reach did not "spotlight" the target object. While we found no preference for any of the individual toys (e.g., the black doll over the white doll), we did find that infants preferred the doll over the truck $t(12) = 2.235$, $p < .05$. Infants who were habituated to reaching for the doll therefore overcame this preference for the doll to look longer at new object trials, in which the actor reached for the truck.

2.3. Discussion

The findings of Experiment 1 replicate those of Woodward (1998) with new objects: infants who were habituated to an actor reaching for one of the two objects in one of the

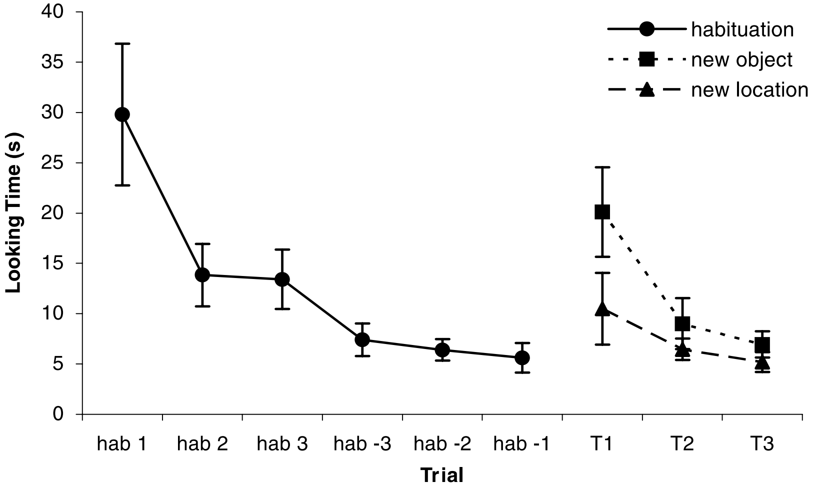

Fig. 1. Habituation curve and test trials in Experiment 1.

two locations generalized habituation over a change in object location more than over a change in the goal object. The findings confirm that infants have a robust tendency to interpret reaching as goal-directed and use feature or kind information to treat the two possible goals as distinct. In the remaining experiments, therefore, we asked which properties of objects infants use to represent the goal of a reach.

3. Experiment 2

In Experiment 2, we asked whether infants are able to construe the reaching action in Experiment 1 coarsely, as directed to an instance of a broad category of objects (doll vs. vehicle) or to the gross features that distinguish these categories (e.g., eyes vs. wheels). We repeated the procedure from the first experiment with one difference: after habituation, the experimenter not only changed the locations of the objects but also switched the object exemplar. That is, if the infant saw a red tow truck on the left and a white male doll on the right, he would see a black female doll on the left and an orange dump truck on the right. If infants treat the goal of a reach as a specific individual or a narrow category of objects, they should look equally long at the two objects during test trials, as the original object no longer appears as an option and therefore leaves the infant with no prediction about the reach. However, if infants construe the goal more broadly, then they should look longer when the person reaches toward the object in the new category.

3.1. Method

The method was the same as Experiment 1 except as follows. Participants were 16 full-term 12-month-old infants, eight boys and eight girls (mean age: 11 months 27 days; range: 11 months 15 days to 12 months 14 days). An additional eight infants were excluded due to fussiness, parental interference, or inability to habituate in 14 trials.

The setup and procedure were as in Experiment 1, except that the actor replaced the original toys with new toys out of sight of the infant after habituation and before the familiarization trial and test trials. If an infant saw the actor reach for the black doll on the right (with the orange truck present on the left), for example, she would then see the actor reach alternately to the white doll on the left and the red truck on the right. Gender, order of test trials, direction of reach, and object reached to in habituation were orthogonally counterbalanced as in Experiment 1.

3.2. Results

As in Experiment 1, repeated measures ANOVAs revealed no main effects of gender, habituation object, object pair used during habituation (red truck/white doll or orange truck/black doll), direction of reach in habituation, or order of test trials, and no significant interaction between these variables. All further analyses were collapsed over these variables.

Fig. 2 presents the looking times during habituation and test trials for Experiments 2. A 2×3 ANOVA revealed main effects of test trial type, $F_{(1,15)} = 8.149$, $p < .05$, and of trial pair, $F_{(1,15)} = 5.154$, $p < .05$, and no interaction between these factors. The analyses also revealed an interaction between order of test trials and trial pair ($F(1,14) = 7.053$, $p < .05$). A closer examination of this effect revealed that infants who saw a new location trial first

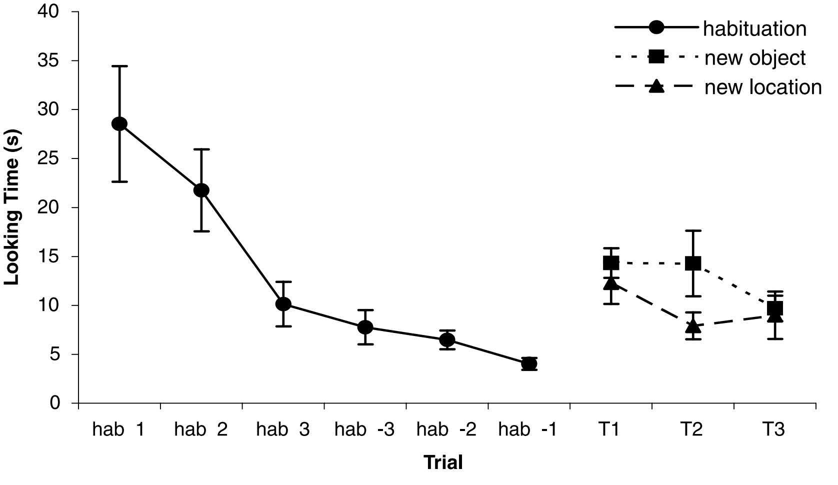

Fig. 2. Habituation curve and test trials in Experiment 2.

and a new object trial second looked significantly longer on the first pair of trials than did infants who saw those two trials in reverse (32.9 and 20.4 s, respectively). The infants who saw the new object reach first likely set a standard for what was novel, meaning that when they saw a reach for a new location, it did not seem novel in comparison. However, infants who saw the new location first did not have a standard of novelty yet, and therefore showed lengthy looking times at what was somewhat novel (e.g. new direction of reach, new arm motion), but then looked just as long at the new object reach, meaning their total looking times in the first pair of trials significantly exceeded those of the "new object first" subset of infants.

The analysis of infants' looking times during the familiarization trial before the test trials again found no significant differences between the proportion of time spent looking at the target object vs. the other object (52.0% vs. 48.0%, respectively), $t(15) = .375$, $p = .713$. As in Experiment 1, we did find that infants preferred to look at the doll over the truck, $t(15) = 4.973$, $p < .001$. Again, infants habituated to reaching for the doll overcame this preference in the test trials to look longer at a reach to the new object category.

Finally, a repeated measures ANOVA, with Experiment as the between subjects factor, compared the findings of Experiments 1 and 2. This analysis revealed a highly significant effect of test trial type ($F_{(1,30)} = 28.544$, $p < .0001$) that did not differ across the two experiments, $F_{(1,30)} = 1.236$, $p = .275$.

3.3. Discussion

The findings of Experiment 2 closely resemble those of Experiment 1. Even though the particular goal object changed in color, detailed shape, race and gender (for dolls), and function (for trucks), infants generalized over these changes and looked longer when the actor reached for an object in a new global category. This tendency to look longer at a reach to a new category was as strong as in Experiment 1. Thus, infants' reaction to the change in the category of the goal of the reach was equally strong, whether the test presented the identical objects or new members of the same category. These findings cast doubt on the thesis that infants interpret the goal of an actor's reach as directed toward either a specific individual object or a narrow category of objects. Rather, any member of the global category of trucks or dolls may satisfy infants' prediction of the actor's future behavior.

Nevertheless, there is an alternative account of the present findings. Infants may have failed to discriminate the two trucks or dolls, despite their markedly different properties. If infants failed to detect the change from one goal object to another, then infants indeed might represent each reach as directed to a specific individual or narrow category of objects and yet fail to apply that representation appropriately to the present events.

An analysis of infants' dishabituation patterns during test trials in Experiments 1 and 2 provides suggestive evidence against this alternative account. When looking times during the last three habituation trials are compared with looking times for each of the two types of test trials, infants showed a significant dishabituation to a reach for the new object in Experiment 1, $t(15) = 3.169$, $p < .01$ for new object trials, but not for the new location trials $t(15) = .643$ $p = .530$. In contrast, the infants in Experiment 2 dishabituated to both the new object trials, $t(15) = 4.964$, $p < .001$, and the new location trials, $t(15) = 3.093$, $p < .01$. These figures suggest that infants discriminated between the objects, dishabituated to changes in the goal objects and then generalized over the distinct members of a common object category.

Results of the analysis comparing Experiments 1 and 2 reveal no overall differences between infants' looking preferences at the original pair of objects vs. the new members of the same global categories during the test trials. Nevertheless, further analyses of infants' patterns of dishabituation to the goal objects suggest a subtle effect of changing the goal objects. Although both Experiments showed overall longer looking times during the new object trials, this effect was driven strongly by the first pair of trials in Experiment 1 (pair 1: $t(15) = 4.320$, $p < .0001$; pair 2: $t(15) = .943$, $p = .361$.; pair 3: $t(15) = 1.202$, $p = .248$). In Experiment 2, because infants first dishabituated to both kinds of test trials, the longer looking times to the new object category were driven by the second pair of trials (pair 1: $t(15) = 1.004$, $p = .331$; pair 2: $t(15) = 2.516$, $t < .05$; pair 3: $t(15) = .311$, $p = .760$). In other words, in Experiment 2, after initially dishabituating equally to the two new exemplars in the first pair of trials, infants continued looking longer only when the actor reached to the object in the new category no longer showing interest in reaches to the old category.

The evidence for discrimination of the different goal objects is, however, indirect. Accordingly, the next experiment tested directly whether infants discriminated, with minimal exposure, between the two dolls and trucks used in Experiment 2.

4. Experiment 3

Experiment 3 used a familiarization/novelty preference method to test infants' discrimination between the pairs of dolls and trucks used in Experiments 1 and 2.

4.1. Method

4.1.1. Participants

Twelve full-term infants, six boys and six girls, with a mean age of 11 months 9 days (range: 11 months 0 days to 11 months 17 days) were tested. One additional subject was excluded due to parental interference.

4.1.2. Displays, design, and procedure

The displays were the same as in Experiments 1 and 2, except that no actor was present behind the stage. At the start of the experiment, the screen was raised and the infant saw either two white male dolls, two black female dolls, two orange dump trucks, or two red tow trucks on the pedestals on stage. After three such familiarization trials (30 s of looking), infants received test trials in which one of the objects from familiarization was paired with a second object from the same category. For example, if the baby had seen two orange trucks during familiarization, he would now see one orange truck and one red truck. Two test trials (each with 10 s of looking) were given, one with the new object on the right, and one with it on the left. Then infants received a second series of familiarization and test trials with a different pair of objects. All infants participated in one block of discrimination trials with dolls and one with trucks. Gender, object pair tested in the first block, object used for familiarization, and side of the switch were orthogonally counterbalanced between infants. A coder who watched the baby on a television in another room, coded when the baby looked at the objects on stage. A familiarization or test trial ended when infants had accumulated 10 s of looking time at the objects.

4.1.3. Data analysis

Two independent, condition-blind coders scored offline the time spent looking at each object in each of the trials, using the method used for scoring the familiarization trial in Experiments 1 and 2. Reliability between coders was over 90% for each trial and 96.6% overall. From the scoring, the proportion of time spent looking at the novel object was calculated for each test trial. Separate one-sample *t*-tests tested discrimination of dolls and of trucks.

4.2. Results

Preliminary analyses revealed no effect of gender, order of test blocks, side of first switch, or object color, so further tests collapsed the data across these variables.

Fig. 3 presents a summary of the findings. Infants showed a significant preference for the novel object, both for the trucks ($t(11) = 2.343$, $p < .05$) and for the dolls ($t(11) = 6.049$, $p < .001$).

4.3. Discussion

Infants discriminated between the two dolls and two trucks used in Experiment 2, even though they generalized from actions on one of these objects to actions on the other. Together with Experiment 2, these findings provide evidence that infants are able to interpret a reach for an object as directed either to a particular global category (such as dolls, people, or animate objects in one case and trucks, vehicles, or artifacts in the other) or to the features that define such a category (such as body shape or presence of a face in one case and angularity or rigidity in the other). In other words, the infants in Experiment 2 did not simply fail to discriminate the two objects within each basic-level category when dishabituated to a reach across kind categories.

Nevertheless, it is possible that infants are able to interpret reaches as directed to individual members of a global category, or to narrower categories of objects, if they are presented with an actor who reaches for one of the two distinct objects from the same basic-level category. Experiment 4 tested this possibility.

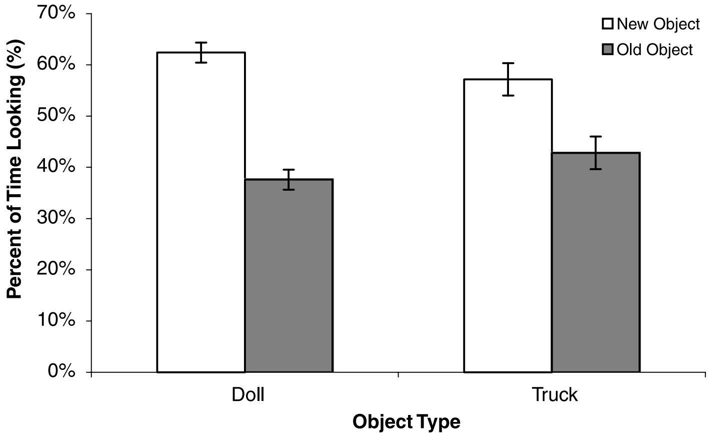

Fig. 3. Percent of time spent looking at each object in Experiment 3.

5. Experiment 4

Experiment 4 investigated whether infants interpret a reach as directed either to a specific object or to a narrowly defined category when a person reaches to one of the two objects in the same basic-level category. The experiment used the method of Experiment 1 with one change: Instead of reaching for one of the two objects of different global categories during habituation and test, the actor reached consistently for one of the two dolls differing in race and gender or to one of the two trucks differing in color, shape, and function. If infants can construe an actor to have a specific object or a narrow object category as her goal, then they should look longer at the new object trials in this condition, as the original object is still present during the test trials and should be exactly the predicted goal of the reach. In contrast, if infants only represent the goal of a reach as a broader category of objects, then they should look equally at reaches to either of the two objects.

5.1. Method

The method was the same as Experiment 1 except as follows. Participants were 20 full-term 12-month-old infants (mean age: 12 months 4 days: range: 11 months 18 days to 12 months 15 days). Ten boys and ten girls were tested with each pair of objects: trucks or dolls. An additional three infants participated but were excluded in analyses due to fussiness or lack of habituation after 14 trials. The objects were the same as in Experiments 1–3, but were paired so that infants saw either the two discriminably different trucks or the two discriminably different dolls. Gender, order of test trials, direction of reach, and object reached for in habituation were counterbalanced for both kinds of objects.

5.2. Results

Because preliminary ANOVAs found no significant differences between infants who saw a reach to one of the two dolls and those who saw a reach to one of the two trucks, all

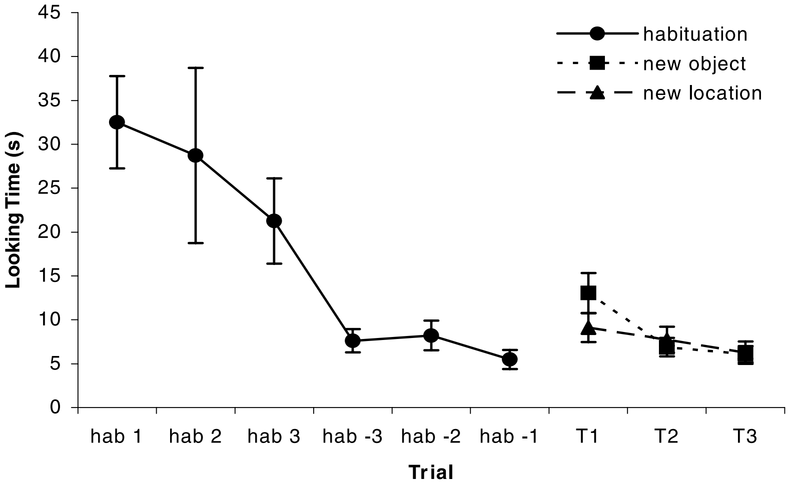

Fig. 4. Habituation curve and test trials in Experiment 4.

further analyses are collapsed across these conditions. In addition, no significant effects were found for gender, order of test trials, direction of reach, or object reached for in habituation, so all final analyses collapsed across these variables as well.

Fig. 4 summarizes infants' looking times during habituation and test trials in Experiment 4. A repeated measures ANOVA revealed a significant effect of trial pair, ($F_{(1,19)} = 7.192$, $p < .05$), and a marginal interaction between trial pair and trial type ($F_{(1,19)} = 3.918$, $p = .06$) but no effect of test trial type ($F_{(1,19)} = .916$, $p = .351$). Infants looked significantly longer in the first pair of test trials than the others, but they looked equally at reaches to the new and old goal objects. Infants showed equal looking to the target object and the other object during the familiarization trial (50.6% and 49.4%, respectively), $t(19) = .244$, $p = .810$. In addition, infants showed no preference for either doll or truck, both $t(9) < 1.0$.

A further 2 (experiment) × 2 (test trial type) × 3 (trial pair) ANOVA compared infants in Experiment 1 with those in Experiment 4. There was a significant interaction between test trial type and experiment, $F_{(1,34)} = 6.703$, $p < .05$. Infants in Experiment 1 looked significantly longer at the new object trials than did infants in Experiment 4.

5.3. Discussion

Experiment 4 provides further evidence that infants interpret a goal-directed reach as directed to a member of a broad category of objects. Even when a person consistently reached for one particular doll or truck rather than another, infants appeared to consider either object as an equally likely and appropriate goal object.

Infants' failure to attribute a narrower goal to the actor is striking, in light of several features of the experiment. First, the two dolls and two trucks were perceptually quite distinct: The dolls differed both in race and in gender, and the trucks differed markedly in their colors, shapes, and functional properties (towing vs. carting and dumping). Second, in Experiment 3, the two dolls and trucks were found to be highly discriminable by infants of this age. Third, analyses of dishabituation patterns in Experiments 1 and 2 suggested that infants detected the switch in goal objects during the reaching events. Nevertheless, the infants in Experiments 2 and 4 did not use any of this detectable featural information to constrain their inferences about the goal of the actor's reach.

Taken together, Experiments 1–4 provide evidence that infants represent the goal of an actor's reach in terms of either its global category membership or its coarse featural properties. However, thus far these experiments have not provided infants with spatiotemporal information to individuate the goal objects. Past research on infants' individuation of objects suggests that tracking properties of objects in the absence of spatiotemporal information may be feasible for infants when the objects belong to widely different categories, but difficult when featural and categorical differences are smaller (Simon, Hespos, & Rochat, 1995). Although 12-month-old infants can individuate objects from distinct global categories when the objects appear at different places and times (Xu & Carey, 1996), they may not be able to do so when two objects belong to the same basic-level kind. In past research, 12-month-olds failed a numerical identity individuation task when the objects were both within one kind category (a coffee mug and a sippy cup) (Carey & Xu, 2001).

Infants' ability to represent objects as spatiotemporally continuous bodies and their limited ability to integrate spatiotemporal and featural information at 12 months could account for all of the findings of Experiments 1 – 4. In Experiments 2 – 4, the change to the objects occurred out of view of the infants. Therefore, if infants viewed the actor's reach as directed to a particular individual object their recognition of the goal object during test trials would depend on their ability to track the goal object over its invisible displacement. It is possible, then, that infants interpreted every reach in Experiments 1, 2, and 4 as directed to a single, persisting object, but they only tracked the object successfully in Experiment 1. In Experiment 2, infants may have generalized from one truck or doll to another because they did not know whether the test trials presented new objects within the same basic-level category or altered versions of the old objects. In Experiment 4, moreover, infants may have failed to look longer at a reach to a new object because they did not know which of the two dolls or trucks presented at test was the object for which the person had previously reached. However, providing infants with spatiotemporal information should allow them to individuate goal objects within the same basic-level category and even treat them as distinct goals. The last two experiments investigated this possibility.

To test whether limits on infants' use of global category information to individuate the goal objects accounted for their equal looking times to the two goal objects in Experiment 4, and also whether infants use spatiotemporal information to track goal objects, a simple change was made to the Woodward (1998) paradigm: the objects were left in full view throughout the experiment. Leaving the objects in view makes available the most effective source of information for their persisting identity and distinctness: information for the *spatiotemporal continuity* of the objects and their motions. Infants have been found to track the identity of inanimate objects in accord with continuity information at every age tested, from 2 to 12 months (Aguiar & Baillargeon, 1999; Spelke, Kestenbaum, Simons, & Wein, 1995; Xu & Carey, 1996). Thus, if infants interpret reaching actions as directed to particular individual objects they should succeed in a version of Experiment 4 in which two trucks are continuously visible.

It is not clear, however, how spatiotemporal continuity information should influence infants' representations of goal-directed reaches toward one of the two dolls. Two lines of research suggest that distinct principles guide infants' tracking of object identity for people vs. inanimate objects. First, Bonatti, Frot, Zangl, and Mehler (2002) used the method designed in Xu and Carey (1996) to study whether infants have separate sortals for "humanlike" or animate objects, whereby they can use property information to individuate objects that cross an animate–inanimate boundary. They found that 10-month-olds, who failed the original Xu and Carey (1996) study using two inanimate objects, did succeed at individuating a doll's head from a non-humanlike object, as well as a dog's head from a doll's head, but did not individuate two dolls' heads from one another. These results suggest that infants may treat dolls not as inanimate objects but as "humanlike," or as stand-ins for people.

Second, recent research suggests that infants do not apply the same principles of object identity to people as they do to inanimate objects. Kuhlmeier, Bloom, and Wynn (2004) used the same paradigm as Spelke et al. (1995) to test 5-month-old infants' representation of the identity of persons vs. large inanimate objects in videotaped events. When presented with events in which a large, moving inanimate object appeared at different places and times, infants represented the identity of the object in accord with the spatiotemporal continuity of its motion, as in past research (Aguiar & Baillargeon, 1999; Spelke et al., 1995; Xu & Carey, 1996). In contrast, when presented with the same events but involving a moving person, infants failed to represent the person's identity in accord with the spatiotemporal continuity of her motion.

These findings raise the possibility that spatiotemporal information will have different effects on infants' apprehension of the identity of trucks vs. "humanlike" items such as dolls (i.e., infants may use spatiotemporal information to individuate two trucks but not do so for two dolls). For this reason, we ran two fully counterbalanced experiments which only differed from one another in the objects seen by the infants—either two dolls (Experiment 5) or two trucks (Experiment 6).

Each experiment used the method of Experiment 4 with one change: Instead of lowering a screen to occlude the actor and the objects between trials, both the actor and the objects remained continuously visible throughout the experiment. When the objects switched position at the end of the habituation period, each object moved visibly (with no apparent cause) on horizontal paths, as in past experiments that tested infants' sensitivity to spatiotemporal continuity (e.g., Spelke et al., 1995). If infants use spatiotemporal information to guide their interpretation of an agent's goal, as they do in object representation, and interpret an actor's reach as directed to a particular, persisting object, then infants who view an actor reaching for one of the two trucks should look longer when she reaches for the other truck. Infants should show the same pattern when the actor reaches for one of the two dolls, if the dolls are treated as inanimate objects. In contrast, if the dolls are treated as animate objects, then infants might look equally when the actor reaches to the two objects, even if they interpret her reaches as directed to a particular, persisting individual, because they may not use the spatiotemporal information provided to individuate the dolls, thus rendering the current experiment a replication of Experiment 4.

6. Experiment 5

Experiment 5 followed the method of the dolls condition of Experiment 4, except that the actor and the dolls were continuously visible.

6.1. Method

The method was the same as Experiment 4, except as follows. Participants were 16 full-term infants (mean age: 11 months 28 days; range: 11 months 15 days to 12 months 18 days). Two additional infants were tested but excluded due to fussiness or experimenter error.

The procedure was as in the dolls condition of Experiment 4, except that the screen used did not occlude the entire stage: it lifted up to cover just the actor's hands and the pedestals on which the dolls sat. At the end of habituation, infants watched as the actor surreptitiously switched the locations of the dolls behind the screen. The actor wore an off-white sheet over her shoulders, thereby disguising her arm motions while switching the location of the dolls. In this way, the infants could watch the dolls move, but did not see the source of their motion. Objects moved slowly and steadily and with no apparent cause, as in past research on spatiotemporal continuity and object identity (e.g., Spelke et al., 1995). Infants were allowed to look at the objects throughout their motion (which lasted about 10 s) and for 5 s thereafter. This period replaced the familiarization trial from the previous studies.

6.2. Results

Preliminary ANOVAs revealed no main effects of gender, direction of reach, order of test trials, or object reached for in habituation, nor any interactions between these variables, and so the analyses collapsed over these variables.

Fig. 5 summarizes infants' looking times during habituation and test trials for Experiment 5. A 2 × 3 ANOVA revealed a main effect of trial pair, $F_{(1,15)} = 17.360$, $p = .001$, but neither main effect of trial type (new object or new location) nor an interaction between trial pair and trial type ($F_{(1,15)} = 2.421$, $p = .141$ for trial type, $F_{(1,15)} = 1.986$, $p = .179$ for the interaction). Infants looked longer at the first pair of trials than the next two pairs of trials, but they did

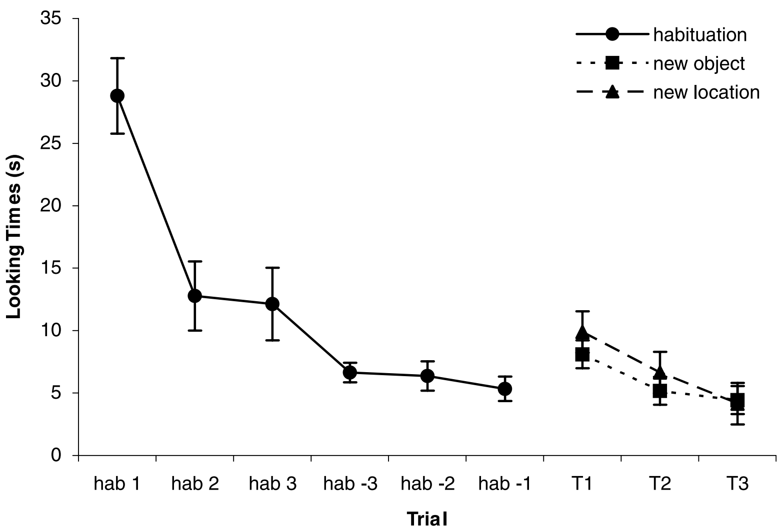

Fig. 5. Habituation curve and test trials in Experiment 5 (Dolls).

not show differential looking to reaches for either of the two dolls. Indeed, infants looked non-significantly longer to a reach to the new location than to a reach to the new goal object.

Paired-sample *t*-tests showed that, as in Experiment 4, infants did not dishabituate to either test event, as their looking times did not differ significantly from their looking times to the last three habituation trials, either for the new object trials ($t(15) = -.271$, $p = .790$) or for the new location trials ($t(15) = .941$, $p = .381$).

A further 2 (experiment) × 2 (trial type) × 3 (trial pair) ANOVA revealed no significant differences in infants' looking times between Experiment 4 and Experiment 5, either to the two trial types ($F_{(1,34)} = 2.399$, $p = .131$) or to the three trial pairs ($F_{(1,34)} = .009$, $p = .923$). There was a significant three-way interaction between experiment, trial type and trial pair ($F_{(1,34)} = 5.350$, $p < .05$). Infants looked longer at the third new object trial in Experiment 4 than to the third new location trial in Experiment 4 or at either of the test trials in the third pair in Experiment 5.

6.3. Discussion

The present findings provide no evidence that infants use the spatiotemporal information provided by the current experimental procedure to interpret an agent's goal more narrowly than the basic-level category of dolls. This finding could be explained in two ways: either infants interpret goals as broad categories of objects (e.g., dolls vs. trucks) but not narrow categories of objects (e.g., male vs. female dolls) or infants interpret goals as individual persisting objects but fail to use spatiotemporal continuity as information for the persisting identity of dolls. Accordingly, the next experiment tested the effects of continuity information on infants' representations of goal-directed reaches for the trucks.

7. Experiment 6

Experiment 6 was identical to Experiment 5 except for the objects that served as the goal of the actor's reach. Actors reached for one of the two trucks, as in the trucks condition of Experiment 4.

7.1. Method

The method was identical to that of Experiment 5 except as follows. Participants were 16 infants (eight boys) of mean age 11 months 28 days on average (range: 11 months 15 days to 12 months 16 days). An additional six infants participated but were excluded due to fussiness, a lack of habituation after 14 trials, or parental interference.

7.2. Results

Preliminary ANOVAs revealed no main effects of gender, direction of reach, order of test trials, or object reached for in habituation, so further analyses collapsed over these variables.[1]

[1] We did find an interaction between direction of reach and trial type ($F_{(1,14)} = 4.832$, $p = .045$). Because we did not find this effect in any of the previous experiments, including Experiment 5, we considered this an artifact of the data.

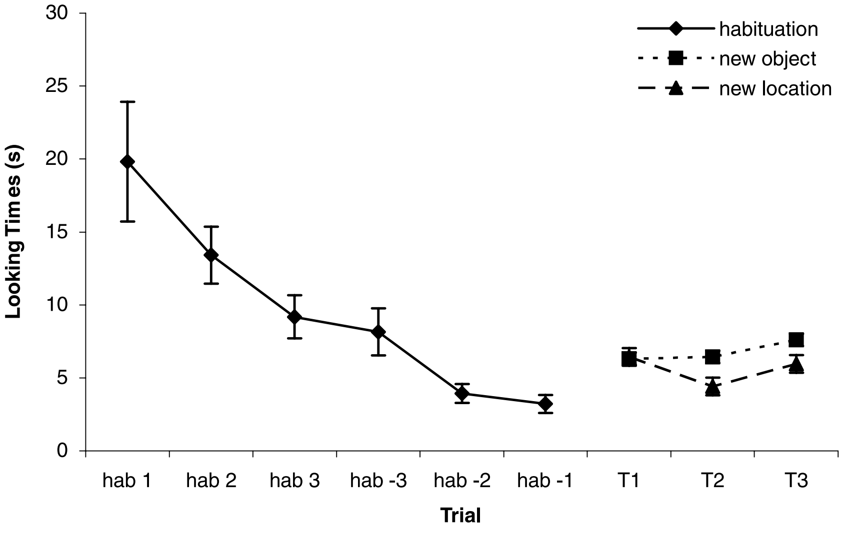

Fig. 6. Habituation curve and test trials in Experiment 6 (Trucks).

Fig. 6 summarizes infants' looking times during habituation and test trials for Experiment 6. A 2 × 3 ANOVA revealed neither main effects of trial pair, $F_{(1,15)} = .028$, $p = .870$, nor trial type (new object or new location), $F_{(1,15)} = .773$, $p = .393$, or an interaction between trial pair and trial type $F_{(1,15)} = .413$, $p = .530$.

Paired-sample t-tests showed that, as in Experiment 4, infants did not dishabituate to either test event, as their looking times did not differ significantly from their looking times to the last three habituation trials, either for the new object trials ($t(15) = .976$, $p = .344$) or for new location trials ($t(15) = -.028$, $p = .978$).

A 2 (experiment) × 2 (trial type) × 3 (trial pair) ANOVA revealed no significant differences in infants' looking times between Experiment 4 and Experiment 6 to the two trial types, $F_{(1,34)} = .024$, $p = .879$, or in a three-way interaction between experiment, trial type and trial pair ($F_{(1,34)} = 2.949$, $p = .095$). We did find a significant interaction between experiment and trial pair ($F_{(1,34)} = 5.274$, $p < .05$). Infants in Experiment 4 did recover their looking times slightly to the first pair of test trials, whereas those in Experiment 6 did not. Likely, the absence of a familiarization trial, where the actor is not present in the display, explains that difference. Infants did not see an actor reappear during the first pair of test trials in Experiment 6 as they did in Experiment 4.

Lastly, we compared looking times between Experiments 5 and 6 in a final 2 × 2 × 3 ANOVA. There was a significant interaction between Experiment and trial pair, $F_{(1,30)} = 11.302$, $p < .01$: whereas infants in Experiment 5 decreased their looking times steadily from the first through the third test pair, infants in Experiment 6 looked about equally long at each of the three test pairs. No other effects were significant.

7.3. Discussion

The findings of Experiment 6 provide no evidence that infants interpret an actor's reach as directed either to a particular goal object (an individual truck) or to a narrowly defined object category (a dump truck rather than a tow truck). Together with Experiments 4 and 5, this study provides evidence that infants interpret reaches as directed to categories of goal objects, at least as broad as the basic level, despite being given appropriate spatiotemporal information to individuate the two possible goal objects.

The principal findings of Experiment 6 did not differ from those of Experiment 5, suggesting that infants treated both dolls and trucks as similar types of goals, presumably as inanimate objects such as toys. Infants may have viewed the dolls as inanimate objects because the dolls served as the goals of reaching actions: actions that characteristically apply to inanimate objects and not to living things or persons.

8. General discussion

The present experiments lend strong support for the hypothesis that infants interpret an agent's goal to be a category of objects at least at the basic level, not a specific, spatiotemporally continuous object (that particular truck) or to a narrowly defined category of object (female dolls or red tow trucks). How broad were the object categories in infants' goal attribution? Because objects in these studies belonged to different categories not only at the basic level (e.g., truck vs. doll), but also at superordinate levels (e.g. vehicles vs. animals, artifact vs. natural kind, inanimate vs. animate object, non-living vs. living objects, non-human vs. human beings), the experiments do not reveal how broadly goal objects are categorized. It is possible that categories are quite broad. Infants who view an actor reaching for a truck may consider a boat or even a chair as equally satisfactory goal objects, depending on the level at which they determine the goals of others. If infants do interpret goals at levels more broad than the basic level, we would expect them not to differentiate reaches to such objects, as in Experiment 4. Further experiments using habituation objects chosen to differ at specific category levels are needed to determine infants' generalization of goal-directed acts more precisely.

While the method in Experiments 1 and 4 can tell us about the default level of specificity at which infants attribute the goals of others, it may underestimate infants' ability to analyze goal-directed action, because it presents infants, at habituation, with reaching to a single object at a single location and on a single path (see Gergely & Csibra, 2003 for discussion). For example, infants might succeed at representing narrower categories or individual objects as goals using spatiotemporal continuity information if the goal objects moved visibly between every habituation trial, and if the actor always reached for that object in different locations. Infants might also succeed at representing a reach as directed to a narrow category of objects if presented with different instances within the same narrow category on different habituation trials.

Nevertheless, we suggest that both the present studies and the research of Woodward (1998) on which it builds, reveal an important set of abilities and limits to infants' analysis of goal-directed action. The vast majority of the actions that humans perform and infants observe, happen only once within a single-event sequence. The customer who reaches for a toothbrush does not aim repeatedly for the same brush as it moves to different positions within the store; he reaches for a single object in a single location. Although repetition with variation can be informative about a person's goal actions, understanding most human actions requires that we determine goals from single events. In this situation, the present findings suggest that global category information is a more robust guide to infants' representation of goal-directed actions and goal objects.

The present findings accord with other findings concerning the categories used by infants of this age in determining object identity and in learning words. By 12 months, infants understand many labels to basic-level categories, such as "truck" and "doll." Moreover, infants of this age are beginning to learn names for objects, primarily at the basic level (e.g., Bloom, 2000). Knowledge of these categories may allow infants to make sense of the actions of agents on objects. For example, if an infant can form the category "doll," then when an agent reaches for a doll, the infant can interpret this event as an agent reaching for "a doll," as opposed to reaching for "the black object with doll-like properties." Then, when the infant sees another object still within the category "doll," he can recognize this as "a doll" and therefore expect the agent to reach to this object. Creating basic-level categories for individuation or for interpreting the goals of an intentional agent may reduce a potentially daunting problem to a manageable task by sorting items in the world into groups, which can then also receive linguistic labels.

The finding that infants do not use spatiotemporal information to interpret goals more narrowly than the basic level is surprising, given the overwhelming evidence in both adult and infant research that spatiotemporal information plays a critical primary role in object representation, and that use of objects' featural and kind properties only occurs later in development as infants learn to integrate these with the spatiotemporal properties of the objects. The current research suggests that infants represent goal objects very differently. Instead of using spatiotemporal information to treat two possible goals within a narrow category as distinct, they use global category information first and foremost to interpret the goal of an agent's reach. This finding also suggests that in Woodward's (1998) experiments, very young infants succeeded in treating two goals from different global categories as distinct because they tracked the feature or kind properties of those objects, and did not require spatiotemporal information about the continuity of the objects in order to do so.

The findings of this series of experiments are surprising for a second reason. Intuition suggests that adults' mechanisms and influences in determining the identity and level of specificity of a goal are extremely nuanced and complex. For example, one would expect adults to re-interpret the goal of an agent based on the contextual cues present in the scene. Adults viewing Experiment 4 would likely interpret the goal of the agent to be quite narrow, as she reached for one truck or doll repeatedly, despite the presence of another truck or doll in the scene (which she should have also reached for equally if her goal had been any member of the category "doll"). Similarly, in the method of Experiment 2, if adults see an actor reach for a dog rather than a chair during habituation, given the choice of a bird or a lamp, adults would use the information about the possible goals both at habituation and test to broaden the level of specificity of the actor's goal in this situation, and would likely expect the actor to reach for a bird during test trials, given the new possible options. Infants, in contrast, appear to be far less flexible in their goal attribution.

What kinds of changes allow children to become more flexible and nuanced in their goal attributions? At least two explanations are possible. First, a qualitative change may occur during development: through maturation and experience, infants and children may come to integrate their system for representing objects with their system for representing actions, such that they can flexibly reinterpret an agent's goal at many levels of specificity. Second, developmental change may be more continuous: infants and children may gradually enrich their conceptions of goal-directed action around a core of global category information that remains privileged for adults. Although adults come to consider diverse information in determining what makes an object, some core properties of objects remain most critical to this process, such as their spatiotemporal continuity and cohesion. When adults are given enough cognitive load, these properties again become primary for adults' object representation, just as they are during infancy (Carey & Xu, 2001; Leslie et al., 1998; Scholl, 2001). Similarly, adults under cognitive load may revert to using global category information to determine others' goals, when contextual conditions favor other patterns of goal attribution.

Infants' attribution of actors' goals at a global category level may support an adaptive learning strategy. To return to the toothbrush example from the introduction, infants may begin by interpreting the action and the goal of someone in the bathroom as "he uses a toothbrush to brush his teeth," with a basic-level categorization of the goal, in a situation where an adult would assume the goal of the actor was that individual object. This approach might have several advantages in fostering learning for the infant. First, by creating coarse categories, the infant can call upon previous experience in more situations by which to make predictions of future behavior (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). The next time the infant sees that person act upon a toothbrush, instead of having created a category for an individual toothbrush and an individual incident, the infant can use his prior experience with toothbrushes to predict this person's behavior.

A second advantage of representing goal-directed actions as directed to coarse categories of objects is that it allows the infant to focus on the actions that are characteristically performed on the objects. The most critical information to learn about goals is how one acts upon them—their function during use. This may occur at a very global level (e.g. people act on animals in some ways and on artifacts in other ways) or at some narrower level (e.g. how one acts on tools vs. vehicles or how one acts on hammers vs. screwdrivers). Therefore, by forming categories regarding the objects upon which actions are performed, an infant can generalize knowledge about action more readily. Moreover, this strategy allows infants to learn about the functional properties of objects, the rules of social interaction, and how actions may generalize to new objects. Infants may over-generalize goal object categories using the actions performed on them to create their categories. Over time, infants may become more flexible about their goal attributions as they learn to refine their default interpretations and to understand exceptions to their heuristics.

If actions performed on or with objects are of primary importance in determining an agent's goal, then function cues should allow infants more flexibility in construing goals than other contextual cues. For example, if an infant sees an actor reach for a spoon and use it either to eat cereal or to knock something over, does she infer the goal of the actor's reach to be the full range of objects that would succeed in performing the eventual action? Wilcox and Chapa (2004) have shown that linking featural properties of objects with a function can cause young infants to use that featural information to individuate objects. It is possible that infants could construe goals more flexibly given richer actions during habituation.

Research with infants and adults has allowed us to understand the core properties that humans use to represent objects, despite the complexity of mature object representations (Scholl, 2001). The current line of research can begin to do the same with action representations. Ultimately, research on the development of action representations may explain how adults can represent and flexibly reinterpret actions at a number of levels, as famously illustrated by John Searle:

> Consider Gavrilo Princip and his murder of Archduke Franz Ferdinand in Sarajevo. Of Princip we say that he produced neuron firing in his brain/contracted certain muscles in his arm and hand/pulled the trigger/fired the gun/shot the Archduke/moved a lot of air molecules/killed the Archduke/struck a blow against Austria/avenged Serbia/ruined Lord Grey's summer season/convinced the Emperor Franz Josef that God was punishing the family/angered Wilhelm II/started the First World War (Searle, 1983).

Through integrated research on adults, children and infants, we may discover both the core properties with which humans start solving the problem of specifying the goals of human actions and the processes by which humans come to attribute goals in more subtle and adaptable ways.

Acknowledgments

We thank Ariana Watson, Becca Pargas, and Ariel Grace for their help in data collection and analysis. We also thank all of the parents and children whose willingness to participate made this research possible. Funding for this research was provided by grants from the National Institute of Health (Grant No. HD23103) to Dr. Spelke.

References

Aguiar, A., & Baillargeon, R. (1999). 2.5-month-old infants' reasoning about when objects should and should not be occluded. *Cognitive Psychology, 39*, 116–157.

Baldwin, D., Baird, J., Saylor, M., & Clark, M. A. (2001). Infants parse dynamic action. *Child Development, 72*(3), 708–717.

Bloom, P. (2000). *How children learn the meanings of words*. Cambridge, MA: MIT Press.

Bonatti, L., Frot, E., Zangl, R., & Mehler, J. (2002). The human first hypothesis: Identification of conspecifics and individuation of objects in the young infant. *Cognitive Psychology, 44*, 388–426.

Carey, S., & Xu, F. (2001). Infants' knowledge of objects: beyond object files and object tracking. *Cognition, 80*, 179–213.

Cohen, L. B., & Younger, B. A. (1983). Perceptual categorization in the infant. In E. K. Scholnick (Ed.), *New trends in conceptual representation* (pp. 197–200). Hillside, NJ: Lawrence Erlbaum Associates.

Eimas, P., & Quinn, P. (1994). Studies on the formation of perceptually-based basic-level categories in young infants. *Child Development, 65*, 903–917.

Gergely, G., & Csibra, G. (2003). Teleological reasoning in infancy: The naive theory of rational action. *Trends in Cognitive Sciences, 7*, 287–292.

Johnson, S., Booth, A., & O'Hearn, K. (2001). Inferring the goals of a nonhuman agent. *Cognitive Development, 16*, 637–656.

Kahneman, D., Treisman, A., & Gibbs, B. (1992). The reviewing of object files: Object-specific integration of information. *Cognitive Psychology, 24*, 174–219.

Kuhlmeier, V., Bloom, P., & Wynn, K. (2004). Do 5-month-old infants see humans as material objects? *Cognition, 94*, 95–103.

Leslie, A., Xu, F., Tremoulet, P., & Scholl, B. (1998). Indexing and the object concept: Developing "what" and "where" systems. *Trends in Cognitive Sciences, 2*(1), 10–18.

Mandler, J. (1992). The foundations of conceptual thought in infancy. *Cognitive Development, 7*(3), 273–285.

McDonough, L., & Mandler, J. (2000). Inductive generalization in 9- and 11-month-olds. *Developmental Science, 1*(2), 227–232.

Meltzoff, A. (1995). Understanding the intention of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology, 31*, 838–850.

Needham, A. (1998). Infants' use of featural information in the segregation of stationary objects. *Infant Behavior and Development, 21*(1), 47–76.

Onishi, K. (2002). *Keeping track of goals when there are two people*. Poster presented at the International Conference on Infant Studies, Toronto, Canada.

Pauen, S. (2002). Evidence for knowledge-based category discrimination in infancy. *Child Development, 73*(4), 1016–1033.

Quinn, P., & Eimas, P. (1993). Evidence for representations of perceptually similar natural categories by 3- and 4-month-old infants. *Perception, 22*, 463–475.

Rosch, E., Mervis, C., Gray, W., Johnson, D., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology, 8*(3), 382–439.

Scholl, B. (2001). Objects and attention: the state of the art. *Cognition, 80*(1–2), 1–46.

Searle, J. (1983). *Intentionality: An essay in the philosophy of mind*. Cambridge: Cambridge University Press.

Simon, T., Hespos, S., & Rochat, P. (1995). Do infants understand simple arithmetic? A replication of Wynn (1992). *Cognitive Development, 10*(2), 253–269.

Spelke, E. (1990). Principles of object perception. *Cognitive Science, 14*, 29–56.

Spelke, E. S., Kestenbaum, R., Simons, D. J., & Wein, D. (1995). Spatiotemporal continuity, smoothness of motion and object identity in infancy. *British Journal of Developmental Psychology, 13*, 113–142.

Wilcox, T. (1999). Object individuation: infants' use of shape, size, pattern, and color. *Cognition, 72*(2), 125–166.

Wilcox, T., & Chapa, C. (2004). Priming infants to attend to color and pattern information in an individuation task. *Cognition, 90*(3), 265–302.

Wilcox, T., Schweinle, A., & Chapa, C. (2003). Object individuation in infancy. In H. Hayne & J. Fagen (Eds.), *Progress in infancy research* (Vol. 3, pp. 193–243). Mahwah, NJ: Lawrence Erlbaum Associates.

Woodward, A. (1998). Infants selectively encode the goal of an actor's reach. *Cognition, 69*, 1–34.

Woodward, A. (1999). Infants' ability to distinguish between purposeful and non-purposeful behaviors. *Infant Behavior and Development, 22*, 145–160.

Woodward, A., & Guajardo, J. (2002). Infants' understanding of the point gesture as an object directed action. *Cognitive Development, 17*, 1061–1084.

Woodward, A., & Sommerville, J. (2000). Twelve-month-old infants interpret action in context. *Psychological Science, 11*, 73–77.

Woodward, A., Sommerville, J., & Guajardo, J. (2001). How infants make sense of intentional action. In B. Malle, L. Moses, & D. Baldwin (Eds.), *Intentions and intentionality: Foundations of social cognition* (pp. 149–169). Cambridge, MA: MIT Press.

Xu, F., & Carey, S. (1996). Infants' metaphysics: The case of numerical identity. *Cognitive Psychology, 30*, 111–153.

Xu, F., Carey, S., & Welch, J. (1999). Infants' ability to use object kind information for object individuation. *Cognition, 70*, 137–166.

Xu, F., Carey, S., & Quint, N. (2004). The emergence of kind-based object individuation in infancy. *Cognitive Psychology, 49*, 155–190.