Chapter 8

The developmental origins of animal and artifact concepts

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As much of this book attests, a wealth of research provides evidence that human infants have a core capacity for representing objects and their motions. The environment contains a diversity of objects, however, with varied properties and behaviors. Objects such as pebbles and blocks are inert; they move or change only in response to an external force. Objects such as butterflies and cars have internal mechanisms generating forces that can propel them. Self-propelled objects can be further differentiated, according to the nature and characteristic pattern of their motions and the circumstances that evoke them. To navigate successfully in this diverse and changing environment, perceivers and actors must categorize the objects around them appropriately, determining what kind of thing each object is and how it is likely to behave.

Here we consider three general accounts of the development of this ability in humans. First, all human learning about objects may be supported by a single core domain that identifies and tracks objects through space and time (e.g., Flombaum et al., Chapter 6; but see Amso and Johnson, Chapter 9). As infants track pebbles and parrots, balls and cars, they may gradually learn that objects fall into general kinds with distinctive properties and behavior (e.g., Spelke, 1990). Second, humans may possess a wealth of distinct core systems for representing objects of different kinds. Early in development, infants may distinguish natural from artifact objects, and they may further distinguish animals, plants, and nonliving natural kinds, as well as people from different social groups and with various properties (Cosmides & Tooby, 1994; Cosmides et al., 2003). Finally, human learning may stem from a very limited set of core domains, such as one for reasoning about social or sentient objects and another for reasoning about all other kinds of objects (e.g., Bloom, 2004; Johnson et al., 1998), or one for reasoning about objects with the capacity for autonomous motion and another for reasoning about objects that lack this capacity (e.g., Baillargeon et al., Chapter 12; R. Gelman, 1990).

Behind these contrasting proposals is a longstanding question, still unresolved, concerning the origins and nature of concepts in human infancy. Are humans' most fundamental concepts, including *person*, *object*, *animal*, and *artifact*, inherent in the human mind and manifest throughout human development, or are they products of learning and experience? Studies of human infants are needed to address this question, using methods that can reveal the signatures of mature conceptual distinctions. In the present chapter, we discuss a new line of experiments on infants that follow this strategy, probing infants' concepts of autonomously moving objects that are natural (i.e., animals) or artifacts (i.e., vehicles). We consider these concepts in relation to two more general ones: the concept *self-propelled object*, which includes both animals and vehicles, and the concept *object*, which includes both self-propelled objects and inert objects such as plants, cups, and rocks.

8.1 **The concept *animal***

Extensive research on the origins of human concepts has focused on the concept *animal* in adults and children. This concept is universal across humans (Atran et al., 2002) and is well established in children by the time they enter school (Carey, 1985; Keil, 1989; S. Gelman, 2003). At the center of this concept are two principles. First, animals belong to *kinds*, whose members share not only perceptible properties but also common internal properties and predispositions (R. Gelman, 1990; S. Gelman & Wellman, 1991; Simons & Keil, 1995). Second, animals move on their own, and their motion is internally generated, directed to goals, and takes efficient paths to those goals (R. Gelman & Spelke, 1981; Massey & R. Gelman, 1988; Viviani & Stucchi, 1992).

Nevertheless, research on children and adults does not clarify the origins of these principles. It is possible that the concept *animal* extends back to infancy. Alternatively, infants may be attuned only to object motions and visual attributes, and they may construct the concept *animal* by learning about correlations of these features with one another and with deeper properties of animals (see Quinn, 2002; Rakison, 2003). Intermediate positions also are possible: Infants may be predisposed to focus on objects and their sources of motion and to form concepts that account for regularities in object structures and functions, fostering rapid learning of concepts of animals and vehicles during infancy (Mandler, 2004).

In recent years, research probing the origins of the concepts *animal* and *vehicle* has centered on methods that probe infants' categorization of objects (for reviews, see Mandler, 2004; Rakison & Poulin-Dubois, 2001; Rakison & Oakes, 2003). Behind this research is the assumption that infants' concepts will be revealed through the categories they form: If infants have a concept *animal*, then they will categorize together perceptually dissimilar objects with the critical attributes of animals (e.g., Mandler & McDonough, 1993, 1998). If infants lack such a concept, then their categorization of objects will depend more directly on the objects' perceptual characteristics, such as possession of particular parts (e.g., Rakison & Butterworth, 1998).

8.2 **Methods for studying infants' concepts**

Infants' categorization of objects has been tested by means of a suite of methods for eliciting object categorization, focusing on visual preference, object manipulation, and deferred imitation. Studies using these methods reveal that infants have an impressive capacity for categorizing animals as distinct from other objects such as vehicles and furniture, on the basis of object appearance (e.g., Behl-Chada, 1996; Mandler & McDonough, 1993, 1996, 1998; McDonough & Mandler, 1998; Pauen, 2002). Because animals and artifacts are highly complex, however, it is not clear what aspects of their appearance are critical to infants' categorization (Pauen, 2002; Rakison & Butterworth, 1998). Moreover, the findings of this research have produced no consensus concerning either the status of infants' categories or the course of conceptual development (see Rakison & Poulin-Dubois, 2001, for a review).

The problem, we believe, lies in the strategy of inferring concepts from the perceptual features used in categorization (Shutts & Spelke, 2004). All categorization of perceptible objects must depend on some perceived properties of those objects, whether or not that categorization is guided by abstract conceptual distinctions. Moreover, there is no systematic metric of shape perception or catalog of object features that would dictate how objects should be categorized in the absence of abstract concepts. For these reasons, studies of feature-based categorization do not reveal whether infants share adults' conceptual categories of *animal* and *vehicle* or form meaningless groupings of objects that are similar in appearance. A consideration of adults' and young children's concepts suggests both the limitations of this strategy and a different approach to the study of concepts in infancy.

Research with adults and preschool children suggests two signature properties of mature *animal* and *vehicle* concepts. First, adults and children expect different kinds of motion from animals versus other artifacts (e.g., R. Gelman & Spelke, 1981; Massey & R. Gelman, 1988). In one study (Massey & Gelman, 1988), for example, 3- and 4-year-old children were shown photographs of animals, vehicles, and rigid objects, and they were asked whether each thing could go up and down a hill on its own. Children judged that only the animals could move in both directions, and reported that even the vehicles could move only downhill by themselves. These findings suggest that children distinguish animals from artifacts of all kinds by three years of age.

Second, adults and children expect animals of the same kind to have similar substance properties (colors and textures) as well as similar shapes, whereas they expect artifacts to vary along substance dimensions. Thus, adults and children attend to information about color and texture when reasoning about animals, but not about artifacts (e.g., Booth & Waxman, 2002; Brown, 1990; Jones & Smith, 1998; Jones et al., 1991; Keil et al., 1998; Lavin & Hall, 2002; Massey & R. Gelman, 1988; McManus & Keil, 2001; Santos et al., 2002). Preschool children tested by Massey and Gelman (1988), for example, used texture information to distinguish photographs of real animals from photographs of animal statues (both of which had animal shapes), and correctly judged that only the former was capable of autonomous motion.

In summary, the mature concept *animal* captures a more abstract set of processes and properties: processes that reveal themselves in the object's behavior, and properties that are specific to an object's substance. These observations suggest an approach to the study of the origins of the concepts in infants. If the mature concepts *animal* and *vehicle* originate in infancy, then infants should show the two same signature patterns of inference. Presented with an object in motion, they should expect the object to move independently only if it possesses animal features and moves like an animal. Moreover, when presented with an object that looks like an animal, infants should generalize learning about that animal's motion to other objects that share its underlying form and substance.

Testing for these signatures requires a method for determining when infants consider an object to be an animal. In the natural world in which human conceptual capacities evolved, the primary perceptual signature of animals is autonomous motion: only animals moved in the absence of an external force. In the modern world, autonomous motion is less clearly a cue to animacy, because vehicles, fans, blenders, and other machines also move through internal forces. These objects appeared only recently in human history, however, and most of them are both started and guided by human agents. If the concept *animal* depends on a cognitive system that emerges early in infancy under the shaping effects of natural selection, then it may be revealed through a method that taps infants' predisposition to attend to and learn about self-propelled motion.

8.3 Infants' learning about self-propelled objects

Our first line of research focuses on infants' reasoning about the movement behaviors of different classes of objects, using a procedure developed by Markson and Spelke (2006) for testing young infants' rapid learning about self-propelled objects. In their experiments, 7-month-old infants were familiarized to events in which one windup toy object engaged in self-propelled motion, whereas a different windup toy object was moved across a stage by hand. Infants were then presented with stationary test trials in which both objects were shown side-by-side alone on the stage. Markson and Spelke (2006) predicted that infants would look longer in stationary test trials at the object that had been previously self-propelled than at the object that had been previously hand-moved, because only the former would be capable of future autonomous motion. The predicted results were obtained in experiments with objects that had animal features and engaged in articulated motion. However, in experiments with toy vehicles or nonsense objects that displayed rigid translatory motion, infants did not demonstrate learning about the differential movement capacities of the objects: they looked equally long at the two objects in stationary test trials.

The pattern of results observed by Markson and Spelke (2006) could be explained in two ways. First, 7-month-old infants' learning about self-propelled motion may be restricted to the domain of animals: Infants may attribute self-propelled motion only to objects with animate features (e.g., eyes, limbs, articulated movement). An experiment by Pauen and Träuble (submitted) supports the idea that infants' attributions of self-propelled motion are specific to objects with animal features. Seven-month-old infants were familiarized to scenes in which two objects—a plastic ball and a hairy worm-like stuffed animal with a face—moved around a stage together. An invisible thread conjoined the two objects so that the source of their joint motion was ambiguous. Following familiarization, infants viewed test trials in which the objects were separated and presented motionless next to one another on a stage. Infants looked longer at the stuffed animal than at the ball, suggesting that they attributed the source of the motion to the object with animal features.

An alternative explanation of the findings of Markson and Spelke (2006) is that infants learn about self-propelled motion for all kinds of objects, but only when the autonomous motion is more complex than rigid translation. Rigid translation may be a poor indicator of self-propelled motion for several reasons. First, in Newtonian mechanics, rigid uniform translatory motion is a default state of all objects, animate or inanimate. As a consequence, children often observe inanimate objects undergoing rigid translation (e.g., a ball that is thrown or struck, an apple that falls from a tree). Consistent with this possibility, research provides evidence that infants who view an object moving after contact with another object do not endow the pushed object with self-propelled motion (e.g., Leslie & Keeble, 1987). Thus, Markson and Spelke's findings are consistent with two quite different views of the origins of infants' learning about objects.

To test the breadth of infants' learning about self-propelled objects in the first year of life, we manipulated category and motion information across three experiments. If young infants' conceptions of animate and inanimate objects are rooted in knowledge of different patterns of movement (e.g., Mandler, 2004), then infants might fail to learn about objects engaging in motions that are not characteristic of animals. Additionally, infants may not be able to learn about self-propelled motion for objects that lack animal features such as a face and limbs. If, however, young infants' learning about objects and their movements is supported by a domain-general system, then infants may learn readily about all kinds of objects, provided their motion is more complex than uniform rigid translation.

The second line of research focuses on infants' generalization of learning about animals. A substantive body of previous research has shown that infants, children, and adults attend to and generalize learning about artifacts by shape over changes in color and texture (e.g., Baldwin et al., 1993; Brown, 1990; Graham et al., 2004; Santos et al., 2002; Welder & Graham, 2001; Wilcox, 1999). In contrast, children and adults generalize learning about animals both by shape and by substance information (color and texture; Booth & Waxman, 2002; Jones & Smith, 1998; Jones et al., 1991; Keil et al., 1998; McManus & Keil, 2001). No research to our knowledge, however, has investigated whether young infants learn and generalize information about animals in accord with their substance properties. To address this question, we investigated younger infants' selective use of shape and color for learning about toy animals. Using Markson and Spelke's (2006) method, 7-month-old infants were given the opportunity to learn, during the experiment, that a toy animal was capable of autonomous, biological motion. Then, we tested whether, and on what basis, infants generalized the capacity for autonomous motion to other toy animals on the basis of shape and color.

8.3.1 **Selective learning about autonomously moving animals**

Our first study used a variation of the method of Markson and Spelke (2006) to investigate whether infants are capable of learning about the self-propelled motion of an object that has animal features, but undergoes rigid, rather than deforming, animate motion. In familiarization trials, 7-month-old infants saw two windup toy animals in alternation on a stage: a pink mouse and a black monkey (Fig. 8.1a). As in Markson and Spelke's (2006) studies, one of the animals was moved passively by a hand that grasped and moved it on the stage. In contrast to their research, however, the other animal moved actively in a motion that is not characteristic of animals: it flipped over backwards in a rigid rotation. After familiarization, infants were presented with the two objects side-by-side and their looking time to each object was recorded.[1] If infants' learning about self-propelled motion is restricted to the domain of objects that engage in the deforming motions characteristic of animals, we reasoned that they would fail to learn about these motion patterns, and their looking preferences at test would be unrelated to the objects' prior patterns of motion. In contrast, if infants learn more broadly about self-propelled motion, we reasoned that they would look longer at the previously self-propelled object during the stationary test trials.

During the familiarization phase, infants looked longer at self-propelled trials than hand-moved trials ($M_{SP} = 42.30$ s, SD = 4.95; $M_{HM} = 40.05$ s, SD = 5.56; $t(15) = 2.22$, $p < 0.05$). During the test trials, infants looked longer at the object that was previously self-propelled than at the object that was previously hand-moved ($t(15) = 2.33$, $p < 0.05$). Fig. 8.2 presents infants' average looking toward each of the objects during the test phase of this experiment.

Infants therefore looked longer, both during familiarization and during the stationary test trials, at the windup animal toy that was previously self-propelled. The present results provide evidence against the hypothesis that infants' capacity for learning about self-propulsion for animates is limited to cases of deforming motions characteristic of animals, as the objects displayed rigid, flipping movements. Infants showed reliable learning about a self-propelled object with animal features, even though the object underwent a rigid rotary motion.

These findings raise the question of whether infants' learning is specific to objects with animal features (e.g., faces, bodies) or whether it also occurs for familiar artifact objects. Although the infants in Markson and Spelke's (2006) experiments failed to learn about the self-propelled motion of a vehicle that underwent a rigid motion, the motion used in their experiment—uniform translation—may have appeared to be the passive response of an inanimate object rather than actively generated, self-propelled motion.

[1] Additional details about methods for all the studies presented in this chapter can be found online at http://www.wjh.harvard.edu/~lds

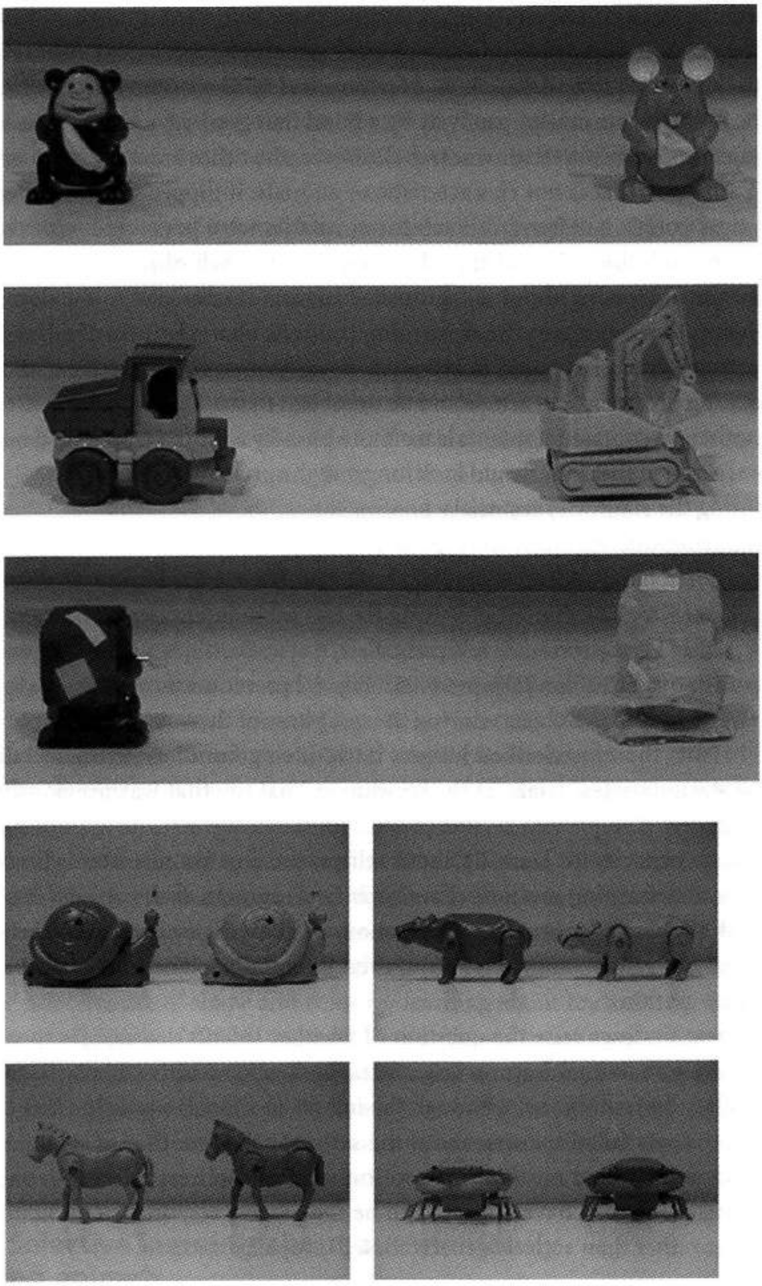
(a)
(b)
(c)
(d)


Fig. 8.1 (a) Animal windup toys, (b) vehicle windup toys, (c) nonsense windup toys, (d) painted animal windup toys used in the studies of learning and generalization.

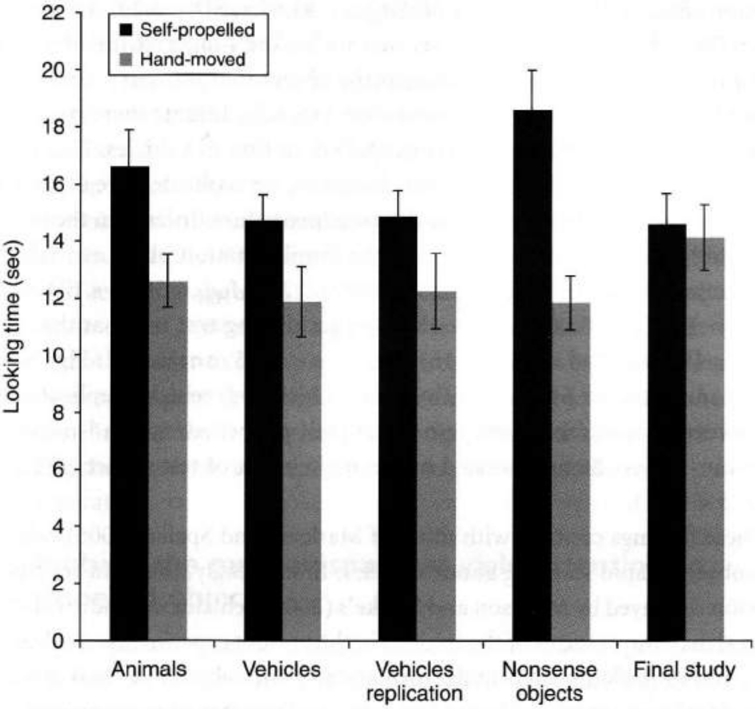


Fig. 8.2 Mean looking times of infants in stationary test trials toward the object that previously exhibited self-propelled versus hand-moved motion. Bars represent the standard error of the mean.

8.3.2 Selective learning about autonomously moving vehicles

Accordingly, we next investigated whether infants learn about the self-propelled motion of complex vehicles. During familiarization, 7-month-old infants saw trials in which one windup toy vehicle (e.g., a dump truck) engaged in nonuniform and nonrigid self-propelled motion, whereas another windup toy vehicle (e.g., a backhoe) was moved around the stage by hand. Following familiarization, infants viewed stationary test trials in which both objects appeared side by side on the stage (Fig. 8.1b). If infants are able to learn about the movement behaviors of vehicles displaying complex motion, they would be expected to look longer at the previously self-propelled object during the test phase.

Once again, infants looked longer during familiarization trials in which the vehicle exhibited self-propelled motion compared with hand-moved motion ($M_{SP} = 45.29$ s, SD = 1.58; $M_{HM} = 41.67$ s, SD = 3.23; $t(15) = 4.36$, $p < 0.001$). During the test phase, infants looked longer at the object that was previously self-propelled than at the object that was previously hand-moved ($t(15) = 2.00$, $p < 0.05$, one-tailed; Fig. 8.2). Infants therefore proved capable of learning about the self-propelled motion of vehicles. Because the test trial effects were relatively weak, however, we replicated the experiment with a new group of infants using the same procedure. Infants in the replication study also looked longer during the familiarization phase at trials with self-propelled motion ($M_{SP} = 42.63$ s, SD = 5.20; $M_{HM} = 38.36$ s, SD = 6.89; $t(15) = 3.91$, $p < 0.001$) and looked longer during test trials at the previously self-propelled object ($t(15) = 2.01$, $p < 0.05$, one-tailed; Fig. 8.2). A repeated-measures ANOVA with study (vehicles vs. vehicles replication) as a between-subject factor and test object (self-propelled vs. hand-moved) as a within-subject factor revealed only a main effect of test object ($F(1,30) = 8.03$, $p < 0.01$).

These findings contrast with those of Markson and Spelke (2006), who did not observe rapid learning about vehicles. Interestingly, the rigid translatory motion displayed by Markson and Spelke's (2006) vehicles was more category-typical than the motions of the vehicles in the present experiments, yet learning occurred in the latter but not the former case. The vehicles we used displayed articulated movements of individual parts and spontaneous changes in path. One or both of these attributes may have contributed to infants' successful learning, perhaps by highlighting or confirming the self-propelled object's capacity for autonomous motion.

8.3.3 **Selective learning about autonomously moving nonsense objects**

Animals and vehicles are both familiar kinds of objects whose real-world counterparts possess internal sources of motion. Both types of objects possess salient features, such as faces and wheels, which infants may use to identify and categorize them. Do infants learn about self-propelled objects only when they are confronted with objects in these familiar categories? We next addressed this question by investigating whether infants are capable of learning about self-propelled 'nonsense' objects that are unfamiliar and that lack the identifying features of either animals or vehicles.

During familiarization trials with self-propelled motion, 7-month-old infants watched one windup toy object (e.g., a pink 'blob') flip over backward as in our first study: a rigid nontranslatory motion. During familiarization trials with passive motion, infants saw a different windup toy object (e.g., a black blob) being tipped forward and back by the experimenter. As in the previous experiments, infants then viewed test trials in which both objects were present but neither moved (Fig. 8.1c).

Yet again, infants' looking was significantly longer for the self-propelled object, both during the familiarization sequence ($M_{SP} = 42.89$ s, SD = 4.26; $M_{HM} = 37.96$ s, SD = 5.54; $t(15) = 4.21$, $p < 0.001$) and at test ($t(15) = 3.81$, $p < 0.01$; Fig. 8.2). Infants therefore learned about the self-propelled motion of unfamiliar objects without animal features or biological motion.

Taken together, these findings provide evidence that infants are broadly capable of learning about self-propelled objects and their movements. A comparison of the present findings to those of Markson and Spelke (2006) suggests that in order to learn about self-propulsion, infants require motion that is more complex than rigid translation of an object from one point to another. Infants may fail to learn from rigid translation because it fails to command their interest, or because it fails to convey that the object's motion is self-generated.

8.3.4 **Probing the mechanisms that yield attention to self-propelled objects**

These findings raise questions about the causes of infants' preferences for self-propelled objects. On average, infants looked significantly longer during familiarization trials with self-propelled motion than during familiarization trials with hand-moved motion. Infants' preference for active over passive motion is not altogether surprising, given that autonomous motion is a marker of agency and therefore might be intrinsically attractive to infants (Premack, 1990). Additionally, previous research has shown that young infants are more engaged by self-propelled than by induced motion (e.g., Crichton & Lange-Küttner, 1999). One concern, however, is that infants' test-trial preference for the object that previously moved autonomously might have been driven by a simple familiarity preference or by a simple preference for an object that previously engaged in complex motion, rather than by an expectation of future self-generated movement.

There are two reasons to doubt the former hypothesis: first, infants tested by Markson and Spelke (2006) did not show a significant preference for the self-propelled over the hand-moved animal during familiarization, but they nevertheless looked longer at that animal during the test trials. Second, infants tested with nonsense objects by Markson and Spelke (2006) *did* show a preference for the self-propelled object during familiarization, but did not look longer at the object during test. These findings suggest that a preference for self-propelled motion is neither necessary nor sufficient for demonstrating this preference when the object is stationary.

To explore further the relationship between familiarization and test preferences in the three studies, a self-propelled familiarization preference score was calculated for each infant by subtracting total looking during hand-moved familiarization trials from total looking during self-propelled familiarization trials. We then used this self-propelled familiarization preference score as a covariate in an analysis of variance. ANCOVA revealed that after controlling for preference during familiarization, preference at test (for the previously self-propelled object) was significant: ($F(1,62) = 4.98$, $p < 0.05$). This analysis also revealed a significant interaction of familiarization preference score and test object ($F(1,62) = 6.39$, $p < 0.05$), suggesting that even though familiarization preferences cannot fully account for test preferences, such preferences do play a role in test effects.

The final experiment in this series was designed to explore further the relationship between familiarization and test preferences by manipulating the relative attractiveness of the two types of familiarization events. As in previous experiments, infants were familiarized with two objects that underwent either autonomous or passive motion, and then they were shown the two stationary objects on test trials. We altered the familiarization events with passive motion, however, to make them more engaging to infants than the familiarization events with autonomous motion.[2] If looking patterns at test are a simple function of interest during familiarization, then infants should look longer, during stationary test trials, at the object whose previous motion was passive.

During the familiarization phase, infants looked significantly longer during the trials with passive motion than during the trials with self-propelled motion ($M_{SP} = 40.31$ s, SD = 4.27; $M_{HM} = 42.37$ s, SD = 3.12; $t(15) = 2.71$, $p < 0.05$). In stationary test trials, however, infants looked equally at both objects ($t < 1$; Fig. 8.2).

Because both the first study (8.3.1) and this last study used objects with animal features, but manipulated the complexity and salience of the motion, their findings were compared directly. To compare looking preferences across studies, we subtracted total looking to the hand-moved from total looking to the self-propelled object both during familiarization and during test, and we conducted a repeated-measures ANOVA with experiment (first study vs. last study) as a between-subject factor and phase (familiarization vs. test) as a within-subject factor. Critically, ANOVA revealed no interaction between experiment and phase ($F < 1$): the increase in infants' preference for the self-propelled object from familiarization to test was equal in both experiments.

[2] See online supporting materials for specific details about the motion.

Thus, presentation of self-propelled motion increased infants' test trial looking in this last study, as it did in the previous experiments, for reasons beyond a simple preference for more interesting motion. Importantly, reversing infants' preference for familiarization events (from a preference for autonomous motion to a preference for passive motion) did not result in a reversal in infants' test preferences, nor did it interfere with the attention-enhancing effects of self-propelled motion. These findings provide evidence that infants are sensitive to the pattern of autonomous motion and use that pattern to learn about self-propelled objects.

In sum, babies distinguish self-propelled objects from objects that cannot move on their own. Beyond the general concept *object*, infants possess and use a narrower concept *self-propelled object*. Nevertheless, the research discussed thus far provides no evidence that babies distinguish self-propelled objects that are *animals* from those that are *artifacts*. It is possible, however, that babies distinguish animals from artifacts such as vehicles, even though they expect both to move on their own. We turn, therefore, to a different series of experiments that probes for the *animal–artifact* distinction by focusing on the second signature of this distinction shown by older children and adults.

8.4 Learning and generalizing information about self-propelled objects

Adults and preschool children view animals, but not artifacts, as members of kinds with a common structure and material composition. As a consequence, adults and children generalize learning about animals both by their shape properties and their substance properties (Booth & Waxman, 2002; Jones & Smith, 1998; Jones et al., 1991; Keil et al., 1998; McManus & Keil, 2001). If asked to imagine that they observe a novel animal with a particular set of properties, children and adults report that other animals of the same kind will be similar to the target animal in shape, texture, and color. In contrast, if asked to imagine that they observe a new artifact, children and adults report that other artifacts of the same kind will be similar in shape but not in texture or color (Keil et al., 1998).

To probe whether infants also distinguish animals from artifacts in this manner, we investigated infants' generalization of learning about animals. In different experiments, we probed generalization based either on the shapes of the animals or on their colors. If infants learn about animals as do older children, then they should generalize learning across animals on the basis of both shape and color.

8.4.1 Generalizing across animals on the basis of shape

In our first study in this series, we tested whether infants generalize learning about the autonomous motion of an animal on the basis of the information that adults and children use in generalizing about both animals and artifacts: shape. Seven-month-old infants participated in two experimental blocks, each comprising six alternating familiarization trials followed by two test trials, as in our previous studies. The stimuli were eight windup toy animals: a blue horse, a tan horse, a blue crab, a tan crab, a pink snail, a green snail, a pink hippo, and a green hippo (Fig. 8.1d). During the familiarization phase of each block, infants viewed windup toy animals differing in shape only (e.g., a blue crab and a blue horse), one of which moved on its own and one of which was moved passively by a hand. For the test, infants viewed new objects with the same shapes but a different color, presented without motion. If infants generalize learning by shape, we expected them to look longer during the test at the object with the same shape as the previously seen object that had moved autonomously.

Results were analyzed with a repeated-measures ANOVA with block (1 vs. 2) and movement (autonomous vs. passive) as within-subject factors. As in the previous experiments, infants looked reliably longer during the familiarization period at the event with autonomous motion, $F(1,15) = 8.03$, $p < 0.05$ ($M_{SP} = 43.27$ s, SD = 2.56; $M_{HM} = 39.26$ s, SD = 5.17). During the stationary test, infants looked longer at the object that shared the same shape as the toy animal that was self-propelled during familiarization ($F(1,15) = 14.84$, $p < 0.01$; Fig. 8.3, left).

Self-propelled familiarization preferences scores were calculated as in previous experiments, and used as a covariate in an analysis of variance. After controlling for preference during familiarization, infants showed a significant preference at test for the object that shared the same shape as the one that had previously moved autonomously ($F(1,14) = 5.13$, $p < 0.05$). Thus, similar to preschool children and adults, infants generalize learning about animals on the basis of shape.

8.4.2 Generalizing across animals on the basis of color

Accordingly, we next investigated whether infants also generalize their learning by color, over a change in shape. During familiarization, infants viewed windup animals differing in color only (e.g., a blue crab and a tan crab), one of which moved autonomously. For the test, infants viewed toy animals of the same colors but a different shape (e.g., a blue horse and a tan horse). If infants have a concept *animal* according to which animals divide into kinds with a common material composition as well as a common structure, then they may show successful generalization by color, just as they generalized by shape in the previous study.

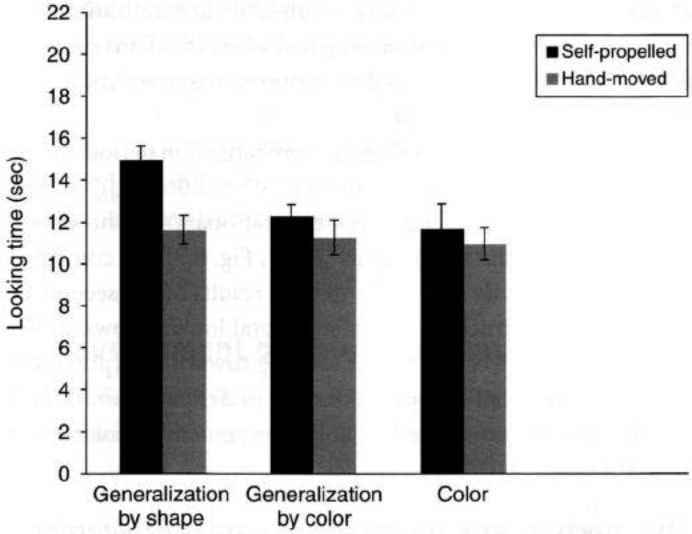


Fig. 8.3 Mean looking times of infants in stationary test trials toward the object that shared the same property (shape or color) as the one that was previously self-propelled versus hand-moved. The graph presents average looking time across two blocks of trials. Bars represent the standard error of the mean.

Infants in this second study looked longer during familiarization trials with autonomous motion compared with passive motion ($M_{SP} = 43.57$ s, SD = 2.79; $M_{HM} = 37.43$ s, SD = 4.09, $F(1,15) = 43.69$, $p < 0.001$). There was no significant effect of block and no significant interaction between movement and block. In contrast, infants showed no looking preference, on the stationary test trials, for the object with the same color and texture as the animal that moved autonomously during familiarization ($F(1,15) = 1.13$, NS; Fig. 8.3).

Infants therefore showed no evidence of generalizing on the basis of color what they learned about the objects they viewed during familiarization. These findings suggest that only shape serves as a basis for infants' learning about animals. Because preschool children and adults show this learning pattern for artifacts but not for animals, the experiment provides no evidence for differentiated animal and artifact concepts in infancy. Nevertheless, it is possible that children take account of substance properties in learning about animals, but do so only when the animals have the same shape (e.g., Jones et al., 1991).

Accordingly, we next investigated whether infants take account of color in learning about animals that are similar in shape. In this third study, infants were familiarized with two toy animals of the same shape but different colors (e.g., a blue crab and a tan crab), one of which engaged in autonomous motion. For test trials, infants viewed the same objects (e.g., the blue crab and the tan crab) without motion. This study therefore required no generalization of learning over a change in shape. Rather, it investigated whether infants can learn about the motion properties of individual toy animals based on color differences alone, when shape is held constant.

Infants again looked longer, during the familiarization period, at the animal that moved autonomously (M_{SP} = 40.35 s, SD = 4.06; M_{HM} = 35.97 s, SD = 5.16; $F(1,15) = 19.64$, $p < 0.001$). For the stationary test, however, infants looked equally long at the two animals ($F < 1$; Fig. 8.3). To compare the test results from the first study (shape) to the test results of the second and third studies (color), we subtracted each infant's total looking toward the (previously) hand-moved object from their looking toward the (previously) self-propelled object. We then compared the test preference scores of infants in these experiments. Infants showed reliably more generalization by shape than by color ($t(46) = 2.30$, $p < 0.05$).

8.4.3 The mechanisms subserving infants' privileging of shape over color

Infants showed no evidence of learning about the movement properties of toy animals on the basis of color, when shape was held constant. In this respect, infants' performance contrasts with that of adults and older children, who use both color and shape in learning about kinds of animals. There are at least two possible interpretations of this negative finding. First, infants may not consider color information when learning about animals. Learning that a given animal engages in self-generated motion may generalize to other animals with the same shape, even if infants only see the movement exhibited by one object of a particular color. Alternatively, infants may not have been able to discriminate between, or remember, the two colors presented during familiarization. The latter alternative is unlikely, because infants have been shown to detect, discriminate, and remember colors in other experiments (e.g., Bornstein et al., 1976). It is possible, however, that this ability would not be shown with the present experiment and displays. A final study was conducted to distinguish between these two interpretations.

We created a test of visual discrimination between the pairs of objects used in the second and third studies. During familiarization, infants saw two motionless toy animals of the same shape and color (e.g., two blue horses) side by side on the stage. For the test, they saw one of the familiarization objects alongside another toy animal that differed from it only in color (e.g., the blue horse and the tan horse). If infants discriminate two animals differing only in color, and they remember the familiar color, they should look longer at the animal with the novel color in the test trials.

During the test trials, infants looked longer at the toy animal with the novel color (M_{NOV} = 3.40 s, SD = 1.37; M_{FAM} = 2.60 s, SD = 1.04; $F(1,15) = 9.42$, $p < 0.01$). This finding provides evidence that infants can perceive, discriminate, and remember the color properties of each of the objects, and it therefore constrains our interpretation of the generalization studies. Although infants can perceive and remember both the shapes and colors of these objects, they learned and generalized learning about self-propelled motion on the basis of shape alone.

8.5 The development of object concepts

The present findings provide evidence that infants make a conceptual distinction between objects that are capable of autonomous motion and those that are not. In the studies described in Section 8.1, infants learned rapidly about the self-propelled motion of a broad class of objects, including animals that displayed rigid rotary motion, vehicles that displayed nonrigid and nontranslatory motion, and unfamiliar objects that engaged in rigid rotary motion. These findings accord with and extend those of previous research on infants' sensitivity to the sources of object motion (e.g., Luo & Baillargeon, 2005; Luo et al., in press; Markson & Spelke, 2006; Pauen & Träuble, submitted).

Nevertheless, the experiments in Sections 8.1 and 8.2 provide no evidence that infants possess the more specific conceptual distinction between self-propelled *animals* and *artifacts*. Infants showed neither of the two signatures of this distinction found in older children and adults. Unlike children and adults, infants' attributions of autonomous motion do not appear to be dependent on category information, or on motions typically associated with particular categories of objects. Infants learned no more readily about self-propelled objects with the features and characteristic motions of animals, than about self-propelled objects with the features and motions of vehicles, or about nonsense objects.

Additionally, unlike children and adults, infants did not learn about animals in accord with both shape and substance properties. Rather, they learned about animals according to the same property they employ when reasoning about novel artifacts: shape. Seven-month-olds infants' reliance on shape accords with findings from research on older infants' attention to shape when learning about artifact objects (e.g., Baldwin et al., 1993; Graham et al., 2004; Wilcox, 1999), as well as with research on children's reliance on shape for word learning (e.g., Graham & Poulin-Dubois, 1999; Jones & Smith, 1998; Jones et al., 1991; see Xu et al., Chapter 11). Their failure to use substance information learning about animals contrasts with the performance of older children and adults (Booth & Waxman, 2002; Jones & Smith, 1998; Jones et al., 1991; Keil et al., 1998; McManus & Keil, 2001), and suggests that infants lack a key signature of the distinction between artifact and natural kinds.

This conclusion is negative, and so it must be offered with caution. It is possible that future work, using different displays, methods, or signatures of the *animal–vehicle* distinction, will find evidence in young infants for some of the principles that guide young children and adults' reasoning about animals and artifacts. Nevertheless, several features of our findings render this possibility unlikely. First, the displays used in the present studies were the same sorts of toy animals and vehicles that have demonstrated successful categorization of animals and artifacts in older infants and children (e.g., Mandler & McDonough, 1998; Rakison & Butterworth, 1998). Second, the signatures for which we tested reflect what may be the deepest properties of animals in relation to artifacts: the role of substance properties in determining and constraining animals' behavior, and the role of autonomous motion in exhibiting that behavior.

Nevertheless, it is possible that other aspects of the *animal–artifact* distinction have earlier roots in human development. In particular, shape information may support generalizations differently over animals versus artifacts. Although infants in the present studies generalized learning about objects in both categories on the basis of object shape, it is possible that the shape descriptions given to animals and to artifacts differ for infants, as they do for older children and adults (e.g., Becker & Ward, 1991; Landau & Leyton, 1999). Despite this possibility, it is clear that some of the most striking markers of the *animal–vehicle* distinction found in children were not observed in the present studies.

Our findings present an interesting contrast with those obtained in studies of adult nonhuman primates using a related looking-time method (Hauser, 1998). Adult cotton-top tamarin monkeys were presented with objects that moved either autonomously or passively in response to external forces, and that either possessed or lacked animal features. Perception of the animacy of the objects was tested by presenting an object, occluding it, and then revealing the object at either the same or a new location. If monkeys represented an object as capable of self-generated motion, they were expected not to be surprised by its change in location, and therefore were expected to show equal looking whether the object was revealed in the same or a different location. By this measure, monkeys distinguished self-propelled animals from passively moved objects, as did the infants in our studies. In contrast to human infants, however, they also distinguished self-propelled animals from self-propelled objects of all other kinds, providing evidence for further distinctions between self-propelled objects that are animate versus inanimate. Because the monkeys were adults, it would be most interesting to repeat these studies with infant monkeys to chart the development of the latter distinction in this species.

Why might human infants have a general concept of *self-propelled object* but not the specific concepts *animal* and *vehicle*? One possible explanation, inspired by evolutionary psychology, is that artifacts such as vehicles are relatively recent inventions. In the environment in which humans evolved, the only objects with the capacity for autonomous motion were animals, and thus a system dedicated to perceiving and reasoning about self-propelled objects would have been sufficient for making inferences about animal kinds.

Researchers interested in the development of the animate–inanimate distinction have proposed a variety of accounts for how infants might construct concepts of animals and artifacts by attention to and analysis of motion information. Both R. Gelman (1990) and Mandler (2004) have suggested that infants' categories are inductively rich and structured around a causal analysis of object motion. Infants are predisposed to analyze the sources of motion of all perceived objects. When they view an object whose motion has no evident external cause, they posit an internal cause to the motion and take that cause to specify its kind. Mandler (2004) has posited that image schemas such as *self-motion* versus *caused motion* and *animate motion* (hypothesized to be 'rhythmic, up and down, and irregular', p. 96) versus *inanimate motion* distinguish animate from inanimate objects and form the basis of infants' earliest categories. On these views, infants' causal analysis gives rise to a primitive concept, *self-propelled object*, from which more specific concepts such as *animal* will arise.

A leaner view has been proposed by others (e.g., Rakison, 2003). Infants may be biased to attend both to object motion and to object parts of any kind. In the environments in which our species evolved, this bias would direct attention toward animals. Attention to global motion and motion of parts may be supported, in turn, by an evolved mechanism for predator and prey detection. Domain-general associative learning mechanisms therefore may allow infants to associate different kinds of static and dynamic object attributes and form categories such as *animals* and *artifacts*. Experiments with younger infants are needed to distinguish these views.

However these questions are resolved, the present research exemplifies a strategy for investigating the origins and early development of category-specific knowledge, modeled on strategies that have been used in recent years to investigate the development of many other aspects of object cognition that are treated in this volume and elsewhere (Carey & Xu, 2001; Scholl, 2001; Shutts & Spelke, 2004). In these studies, we investigated whether young infants show critical signatures of the conceptual distinctions made by older children and adults. Children and adults distinguish animals from artifacts on the basis of both their part structures and their characteristic motions. Moreover, children and adults selectively learn and generalize information about objects along different dimensions, depending on the domain to which the objects belong. With the present methods, investigators can ask when in development humans begin to display these signature patterns. In light of our findings that infants fail to show the central signatures of concepts such as *animal*, future studies can probe the circumstances under which these signatures begin to appear, thereby tracing how maturation and specific experiences shape children's emerging concepts.

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