WHO’S GOT GUTS?
YOUNG INFANTS EXPECT ANIMALS TO HAVE INSIDES

BY

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THESIS

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ABSTRACT

What are the developmental origins of our concept of animal? There has long been controversy concerning this question. At issue is whether biological reasoning develops from earlier forms of reasoning, such as physical and psychological reasoning, or whether from a young age children endow animals with biological properties. Here we demonstrate that 8-month-old infants already expect novel objects they identify as animals to have insides. Infants detected a violation when an object that was self-propelled and agentive (but not an object that lacked one or both of these properties) was revealed to be hollow. Infants also detected a violation when an object that was self-propelled and furry (but not an object that lacked one or both of these properties) either was shown to be hollow or rattled (when shaken) as though largely hollow. Young infants’ expectations about animals’ insides may serve as a foundation for the development of more advanced biological knowledge.
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CHAPTER 1
INTRODUCTION

By the end of the preschool years, children possess considerable biological knowledge. In particular, they expect the insides of animals to be different from those of artifacts (Gottfried & Gelman, 2005; Simons & Keil, 1995); they realize that the insides of an animal are essential for its functioning (e.g., a dog cannot bark after its insides are removed) (Gelman & Wellman, 1991; Gottfried, Gelman, & Schultz, 1999); and they are beginning to understand that certain behaviors, such as eating and drinking, are necessary to maintain the continued functioning of animals and their insides (Inagaki & Hatano, 1993; Morris, Taplin, & Gelman, 2000). This early biological knowledge is often characterized as a vitalistic biology in which internal organs and their workings sustain the vitality or life force of animals (Carey, 2000; Gutheil, Vera, & Keil, 1998; Hatano & Inagaki, 1994; Inagaki & Hatano, 2004). Does this vitalistic biology have roots in infancy? Do infants possess abstract expectations about animals that could lay the foundations for the development of more advanced biological knowledge? Below, we consider two broad hypotheses concerning these questions; we refer to them as the non-biological and the biological hypotheses.

According to the non-biological hypothesis, infants do not yet endow animals with any vitalistic or biological properties: Animals are simply entities that are self-propelled and agentive (for infants, these two properties are conceptually distinct (Baillargeon & Wu, 2009; Csibra, 2008; Shimizu & Johnson, 2004)); objects may be self-propelled without being agentive, and they may be agentive without being self-propelled). Proponents of the non-biological hypothesis differ greatly in their theoretical perspectives on how infants come to understand self-propulsion and agency. According to the core-domain view (Carey, 1988), for example, infants’ concept of
self-propulsion is part of the skeletal explanatory framework that underlies core physical reasoning: When a novel object gives evidence that it is capable of autonomous motion (e.g., begins to move on its own), infants attribute to the object an internal source of energy, and they appreciate that the object may use its energy to reverse course, resist efforts to move it, resist falling when released in midair, and so on (Luo, Kaufman, & Baillargeon, 2009). Similarly, infants’ concept of agency is part of the skeletal explanatory framework that underlies core psychological reasoning: When a novel object provides evidence that it has autonomous control over its actions (e.g., responds contingently to events in its environment), infants attribute to the object motivational, epistemic, and other internal states, and they use these states to predict and interpret the object’s actions (Johnson, Shimizu, & Ok, 2007). In contrast, the image-schema view (Mandler, 2012) assumes that infants’ concepts of self-propulsion and agency are formed by a perceptual-meaning-analysis mechanism that re-describes spatiotemporal information into meaningful iconic representations. Thus, self-propelled objects are those that start moving by themselves, without contact with other objects, whereas agentive objects are those that interact contingently with other objects, again without contact. In the image-schema view, infants have no notion of internal energy or internal states—these concepts are acquired later in development, as enrichments of primitive spatial concepts. Despite their marked differences, however, both the core-domain view and the image-schema view assume that animals are, for infants, no more than self-propelled agents.

This assumption contrasts with the biological hypothesis, which admits the possibility that infants immediately ascribe to entities that are self-propelled and agentive additional properties that are vitalistic or biological in nature (Gelman, 1990; Keil, 2007; Opfer & Gelman, 2010; Waxman, 2005). What might these biological properties be? One specific proposal, put
forth by R. Gelman (Gelman, 1990), is that infants are born with an *innards* principle: objects that are self-propelled and agentive “have something on the inside” that makes possible their behavior (p. 91). According to Gelman, “the principle is neutral with respect to the nature of what a child or anyone may think is in the inside” (p. 91). The innards principle is, of course, consistent with the findings on vitalistic biology reported earlier: Children might at first simply expect animals to *have* insides, and with experience they might gradually learn how the insides of animals differ from those of artifacts (Gottfried & Gelman, 2005; Simons & Keil, 1995), how the insides of specific kinds of animals differ from those of other animals (Gelman & O’Reilly, 1988; Waxman, Medin, & Ross, 2007), and so on. In line with the innards principle, Gelman (1990) found that when asked what was on the inside of various artifacts and animals, children age 3 years and older sometimes said that an artifact had nothing on the inside, but they never said that an animal had nothing on the inside.

Is the non-biological or the biological hypothesis correct? One way to address this question is to test whether young infants expect objects that are self-propelled and agentive to have insides, in accordance with the innards principle. Therefore, we used the violation-of-expectation method to ask whether 8-month-olds would detect a violation when a novel object that was self-propelled and agentive—but not an object that lacked one or both of these properties—was revealed to be hollow, like an inverted bowl. We reasoned that positive results would support the biological hypothesis by demonstrating that infants attribute to self-propelled agents additional properties that are biological in nature.

How likely were infants to attend to the insides of novel objects? Prior research with 14-month-olds indicates that infants do notice some objects’ insides. For example, infants assigned perceptually different objects with eyes to the same category if they possessed similar insides
(Welder & Graham, 2006); infants readily formed an association between a transparent object’s self-propelled motion and the presence of an internal part (Newman, Herrmann, Wynn, & Keil, 2008); and infants also readily associated a transparent object’s particular style of self-propelled motion with the color of its internal part (Träuble & Pauen, 2011). Given these results, it seemed plausible that younger infants might also attend to the insides of novel objects.
CHAPTER 2
EXPERIMENT 1

In Experiment 1, 8-month-olds from English-speaking families \( n = 36 \) watched live events involving two novel objects: a large can covered with alternating stripes of red and grey yarn and a large box covered with beige paper and varying round patches of blue cloth with multicolored dots. Infants were assigned to a self-propelled/agentive condition or a non-self-propelled/non-agentive condition. All infants received two familiarization trials, two pretest trials, and two test trials, one with the can and one with the box; half the infants received the can trial first in each pair of trials, and half received the box trial first. Only the familiarization trials differed between the two conditions. Each familiarization trial had an initial phase and a final phase; looking times during the two phases were computed separately. At the beginning of the \((76\text{-s})\) initial phase of the can trial in the self-propelled/agentive condition (Fig. 1a), the can rested at the center of the apparatus floor. To start, the can moved in a slight bouncing manner back and forth across the floor and then returned to its original position (this displacement lasted about 16 s and served to establish that the can was self-propelled; Luo et al., 2009). Next, a female experimenter opened a window in the back wall of the apparatus; the can then initiated a “conversation” by quacking at the experimenter, who responded contingently (this exchange lasted about 49 s and served to demonstrate that the can was agentive; Johnson et al., 2007). Finally, the experimenter left, closing her window behind her. During the final phase of the trial, the can rested at the center of the apparatus, and infants watched this paused scene until the trial ended. The box familiarization trial was identical except that the box moved in a slight zigzag manner and beeped at the experimenter. Infants in the non-self-propelled/non-agentive condition (Fig. 1b) received similar familiarization trials except that the can and box remained stationary.
(thus providing no evidence that they were self-propelled; Luo et al., 2009), and the experimenter remained silent in response to the can’s quacks or the box’s beeps (thus providing no evidence that they were agentive; Shimizu & Johnson, 2004).

Next, all infants received the can and box pretest trials (Fig. 1e), which served to introduce infants to the actions performed in the test trials. In each trial, the experimenter lifted the can or box with both hands, tilted it right and left twice, returned it to the apparatus floor, and then repeated this entire (12-s) sequence until the trial ended. Finally, all infants received the can and box test trials (Fig. 1f). These were identical to the pretest trials except that, before tilting the can or box from side to side, the experimenter rotated it to reveal its bottom to the infant. When the objects were rotated, infants could see that one was hollow, like an inverted bowl (hollow trial), whereas the other one was closed, like a block (closed trial). For half the infants in each condition, the can was hollow and the box was closed; for the other infants, the reverse was true.

2.1 METHODOLOGY

Participants

Participants were 36 full-term infants (18 males, range: 7 months, 3 days to 9 months, 11 days). Mean ages were 8 months, 4 days. Another 6 infants were tested but excluded because they looked the maximum time allowed in both test trials (5), or was distracted (1).

Apparatus

The apparatus consisted of a brightly lit display booth (183 cm high × 100 cm wide × 57 cm deep) with a large opening (55 cm × 94 cm) in its front wall; between trials, a supervisor lowered a curtain in front of this opening. Inside the apparatus, the side walls were painted white, and the back wall (made of foam core) and floor were covered with colored adhesive paper. The experimenter was a female native English speaker. She wore a green shirt and sat at a window
(34 cm × 48 cm) in the back wall of the apparatus; this back window could be closed with two identical doors. A large screen behind the experimenter hid the testing room. The can (18 cm × 17 cm in diameter) was wrapped with red and gray yarn in alternating stripes; the can had a removable gray felt bottom, and its interior was lined with beige felt. The box (18 cm × 18 cm × 18 cm) was covered with beige adhesive paper and decorated with varying round patches of blue cloth with multicolored dots; the box had a removable beige felt bottom, and its interior was lined with brown felt. In the familiarization trials, a long flat handle was attached to the bottom of the can or box and protruded through a narrow slit at the bottom of the back wall. In the self-propelled conditions, the experimenter used the handle to move the can (in a slight bouncing manner) and the box (in a slight zigzag manner) along the apparatus floor, between predetermined marks. In the familiarization trials, the can or box also held a small speaker; its wire was tied to the handle and was connected, behind the apparatus wall, to an MP3 player. The can produced varying synthesized quacking sounds and the box produced varying beeping sounds; these sounds were pre-recorded on the MP3 player and played through the speaker in the can or box. In the agentive conditions, a small reminder card with the written conversation script was attached to the back of the can or box for the experimenter to follow; in the non-agentive conditions, the can and box produced the same sounds but the experimenter remained silent. During each test session, one camera captured an image of the events, and another camera captured an image of the infant. The two images were combined, projected onto a television set located behind the apparatus, and monitored by the supervisor to confirm that the trials followed the prescribed scripts. Recorded sessions were also checked off-line for accuracy.

Procedure

Infants sat on a parent’s lap in front of the apparatus; parents were instructed to remain
silent and to close their eyes during the test trials. Two hidden observers helped monitor infants’ looking behavior and the primary observers’ responses were used in the analyses. The primary observer left the test room during the familiarization trials in order to be naive during the pretest and test trials about infants’ condition and trial order. Inter-observer agreement during the test trials averaged 95% per trial per infant. Infants were attentive during the initial phases of the two familiarization trials and looked, on average, for 81% of each initial phase. The final phase of each familiarization trial ended when infants (1) looked away for 2 consecutive seconds after having looked for at least 2 cumulative seconds or (2) looked for a maximum of 60 cumulative seconds. Each pretest and test trial ended when infants (1) looked away for 1 consecutive second after having looked for at least 5 cumulative seconds or (2) looked for a maximum of 50 cumulative seconds; the 5-s minimum value ensured that infants had the opportunity to observe the rotated objects in the test trials.

Preliminary analyses of the test data in this report revealed no interactions of condition and trial with infants’ sex or with order of the test trials; the data were therefore collapsed across these factors in subsequent analyses.

2.2 RESULTS AND DISCUSSION

Analysis of infants’ looking times during the test trials (Fig. 2) revealed a significant Condition X Trial interaction, $F(1, 34) = 5.98, p = .020$ (no such interaction was found in an analysis of the final phases of the familiarization trials or in an analysis of the pretest trials, both $F$s(1, 34) < 1). Planned comparisons revealed that in the self-propelled/agentive condition, infants looked reliably longer during the hollow than the closed trial, $F(1, 34) = 9.68, p = .004$; 15/18 infants showed this pattern. In the non-self-propelled/non-agentive condition, in contrast, infants looked about equally during the two trials, $F(1, 34) < 1$; 7/18 infants looked longer at the
hollow event. Thus, infants detected a violation when the can and box were shown to be hollow, but only if they were self-propelled agents; if the objects were neither self-propelled nor agentive, infants held no expectations about whether they should have insides.
CHAPTER 3
EXPERIMENT 2

To investigate the specificity of infants’ expectations about what objects should have insides, in Experiment 2 additional 8-month-olds from English-speaking families \((n = 54)\) were assigned to one of three conditions. The *self-propelled/agentive* condition was identical to that in Experiment 1 (Fig. 1a). The other two conditions were similar except that in the familiarization trials either the experimenter remained silent (*self-propelled/non-agentive* condition; Fig. 1c), or the can and box remained stationary (*non-self-propelled/agentive* condition; Fig 1d).

3.1 METHODOLOGY

*Participants*

Participants were 54 full-term infants (27 males, range: 7 months, 7 days to 9 months, 9 days). Mean ages were 8 months, 1 day. Another 17 infants were tested but excluded because they looked the maximum time allowed in both test trials (10), because they were fussy (4), or was distracted (2), or because the difference in their looking times during the two test trials was over 2.5 standard deviations from the condition mean (1).

*Apparatus*

The apparatus was the same as Experiment 1.

*Procedure*

The procedure was the same as Experiment 1. Inter-observer agreement during the test trials averaged 96% per trial per infant. Infants were attentive during the initial phases of the two familiarization trials and looked, on average, for 87% of each initial phase.

Preliminary analyses of the test data in this report revealed no interactions of condition
and trial with infants’ sex or with order of the test trials; the data were therefore collapsed across these factors in subsequent analyses.

3.2 RESULTS AND DISCUSSION

Analysis of infants’ looking times during the test trials revealed a significant Condition X Trial interaction, $F(2, 51) = 3.58, p = .035$ (no such interaction was found in an analysis of the final phases of the familiarization trials, $F(2, 51) < 1$, or in an analysis of the pretest trials, $F(2, 51) = 1.10, p = .340$). In the self-propelled/agentive condition, as before, infants looked reliably longer during the hollow than the closed trial, $F(1, 51) = 6.98, p = .011$; 14/18 infants showed this pattern. In contrast, infants looked about equally during the two trials in both the self-propelled/non-agentive and non-self-propelled/agentive conditions, both $Fs < 1$; 8/18 infants in each condition looked longer during the hollow trial. Thus, infants expected the can and box to have insides only if they were self-propelled and agentive; if they lacked either property, infants held no expectations about their insides.

The findings of Experiments 1 and 2 are important for three reasons. First, they provide new evidence that infants distinguish self-propelled agents from objects that are only self-propelled or only agentive; infants do not expect all self-propelled objects to be agentive, nor do they expect all agentive objects to be self-propelled. Second, the results indicate that infants expect a novel self-propelled agent to have insides, in accordance with the innards principle. Finally, the results support the biological hypothesis by demonstrating that infants already possess abstract expectations about the insides of animals.
Proponents of both the non-biological and biological hypotheses assume that, with experience, infants learn to use details of surface appearance and form as cues that novel objects are animals (this cue-learning process enables infants to rapidly identify novel animals without having to wait for evidence of autonomous motion and control). For example, previous research indicates that, by 7 months of age, infants already use fur on a self-propelled object as a cue that the object is an animal (Träuble & Pauen, 2011). When a ball and a furry object with a face moved together in close contact, infants attributed the source of the motion to the furry object; when the two objects later rested stationary side by side, infants looked reliably longer at the furry object as though they anticipated that it would move again. However, no such effect was found when an experimenter moved the ball and the furry object together with her hand. (In a survey we conducted of parents of 35 6- to 9-month-olds, 83% reported that their infant had touched a furry animal at least once, and 60% reported that their infant had regular contact with one or more furry animals. These results support the notion that infants in the second half-year have opportunities to identify fur as a predictive cue for animals). Building on these results, we asked in Experiment 3 whether 8-month-olds would expect an object that was furry and self-propelled, but not an object that lacked one or both of these properties, to have insides.

Infants \((n = 26)\) were assigned to a self-propelled or a non-self-propelled condition, and they watched events involving a new can that was covered with brown beaver fur and a new box that was covered with tan paper and edged with brown tape (Fig. 3). During the (32-s) initial phase of each familiarization trial in the self-propelled condition, the fur-can or box moved smoothly back and forth across the apparatus floor, to demonstrate that it was self-propelled;
during the final phase, the object paused at the center of the apparatus until the trial ended. The familiarization trials in the non-self-propelled condition were identical except that the fur-can and box rested on a tray, and the experimenter reached through a window in the back wall of the apparatus to move the tray back and forth. Next, all infants received pretest and test trials identical to those in Experiment 1 except that the fur-can (fur-can trial) and box (box trial) were both revealed to be hollow.

4.1 METHODOLOGY

Participants

Participants were 26 full-term infants (13 male, range: 6 months, 20 days to 9 months, 13 days). Mean ages were 8 months, 26 days. Another 4 infants were tested but excluded because they looked the maximum time allowed in both test trials (2), because they were distracted (1), or overly active (1).

Apparatus

The apparatus was the same as Experiment 1 except for the following differences. The window in the back wall of the apparatus that could be closed with two identical doors measured 25 cm × 48 cm. Instead of a yarn can, a fur-can (about 15 cm × 22 cm in diameter) was used. It consisted of a brown beaver fur hat that was placed over an upright cylinder in the familiarization trials of the self-propelled condition; and in the fur-can pretest and test trials, the upright cylinder was replaced by an inverted cylinder lined with tan felt. Instead of the beige box, a box (15 cm × 18 cm × 18 cm) was covered with tan packing paper and edged with brown tape was used. In the box pretest and test trials, an exact copy of the box was used that had no bottom and was lined with brown felt. In the familiarization trials of the self-propelled condition, the fur-can or box was again attached to a long flat handle; behind the wall, the experimenter used the
handle to move the object smoothly back and forth between pre-determined marks. In the familiarization trials of the non-self-propelled conditions, the fur-can or box rested on a pink tray (5 cm × 29 cm × 23 cm) with handles that was moved by the experimenter from the back window. The experimenter moved the tray in such a way that the fur-can and box travelled the same distance as in the corresponding self-propelled condition.

Procedure

The procedure was the same as Experiment 1. Inter-observer agreement during the test trials averaged 93% per trial per infant. Infants were attentive during the initial phases of the two familiarization trials and looked, on average, for 85% of each initial phase.

Preliminary analyses of the test data in this report revealed no interactions of condition and trial with infants’ sex or with order of the test trials; the data were therefore collapsed across these factors in subsequent analyses.

4.2 RESULTS AND DISCUSSION

Analysis of infants’ looking times during the test trials yielded a significant Condition X Trial interaction, $F(1, 24) = 7.08, p = .014$ (no such interaction was found in an analysis of the final phases of the familiarization trials or in an analysis of the pretest trials, both $F$s$(1, 24) < 1$). In the self-propelled condition, infants looked reliably longer during the fur-can than the box trial, $F(1, 24) = 16.22, p = .001$; 12/13 infants showed this pattern. In contrast, infants in the non-self-propelled condition looked about equally during the two trials, $F(1, 24) = 0.80, p = .795$; 7/13 infants looked longer during the fur-can trial. Thus, infants expected the self-propelled fur-can to have insides, but they held no expectation about the insides of the non-self-propelled fur-can or about those of the box, whether it was self-propelled or not. These results also provide additional evidence that by 8 months infants use fur on a self-propelled object as a cue that it is an animal.
In Experiments 1-3, infants detected a violation whenever an object they had identified as an animal was revealed to have no insides. To provide converging evidence for these results, in Experiment 4 we used a different manipulation to assess 8-month-olds’ expectations about insides: instead of rotating the fur-can and box from Experiment 3, the experimenter shook each object to demonstrate that it rattled, as though the shaking caused a few parts to bounce inside the object’s largely hollow interior. If infants expected the self-propelled fur-can to have insides, they should detect a violation when it produced a rattling noise when shaken, as though it was largely hollow inside. (To check our manipulation, we presented 20 adults with the rattling fur-can and the rattling box, and we asked them to estimate based on the sounds they heard how full each object was inside. On average, subjects guessed that the objects were 28% full, supporting our claim that the rattling sounds conveyed that the objects were largely hollow).

Infants \((n = 51)\) were assigned to a self-propelled, a non-self-propelled, or a control condition (Fig. 4). In the \textit{self-propelled} condition, infants received the same fur-can and box familiarization trials as in the self-propelled condition of Experiment 3, for two pairs of trials. Next, infants received either a fur-can or a box test trial. During the (25-s) initial phase of each trial, the experimenter’s gloved hands (which reached through a curtained window in the right wall of the apparatus) first grasped the fur-can or box. Next, the hands lifted the object, shook it (causing it to rattle), and returned it to the apparatus floor; this sequence was repeated two more times, and then the hands rested on either side of the object. During the final phase, infants watched this paused scene until the trial ended (pilot data indicated that infants tended to look
continuously if the rattling persisted, so this non-repeating procedure was used instead). The
*non-self-propelled* condition was identical except that in the familiarization trials the fur-can and
box rested on a tray, and the experimenter’s right gloved hand moved the tray back and forth on
the apparatus floor. Finally, because infants in the self-propelled condition might look longer
when the fur-can rattled not because they expected it to have insides but because they had never
seen an animal being shaken before, a *silent-control* condition was also included. This condition
was identical to the self-propelled condition except that in the test trials the objects produced no
noise when shaken.

5.1 METHODOLOGY

*Participants*

Participants were 51 full-term infants (26 male, range: 6 months, 17 days to 8 months, 5
days). Mean ages were 7 months 15 days. Another 3 infants were tested but excluded because
they were fussy (2), or drowsy (1).

*Apparatus*

The apparatus was the same as Experiment 3 except for the following differences. In
experiment 4, the experimenter wore long silver gloves and reached through a window (51 cm ×
38 cm and filled with a fringed curtain) in the right wall of the apparatus. In the familiarization
trials of the non-self-propelled conditions, the fur-can or box rested either on a yellow tray (5 cm
× 23 cm × 29 cm) without handles that was moved by the experimenter’s right gloved hand from
the right window, and the fur-can and box travelled the same distance as in the corresponding
self-propelled condition. The fur-can always sat on the upright cylinder and the box used had a
closed bottom. In the test trials with rattling sounds, a small plastic bag filled with 22 l-cm metal
bells was partly affixed to the interior bottom surface of the fur-can or box; when the object was shaken briskly up and down, the bag bounced against the rigid bottom of the object, producing rattling sounds.

Procedure

The procedure was the same as Experiment 3 except that in Experiment 4, observers could use available sounds to determine which test trials were shown; therefore, all final phases of the test trials were recoded frame-by-frame by two independent coders from edited silent videos. The two coders agreed on 97% of coded frames (trials with agreement below 90% were resolved through discussion). Infants received two pairs of familiarization trials and 1 test trial, and each trial had an initial and a final phase. Across conditions, infants looked, on average, for 83% of each initial phase. The final phase of each trial ended when infants (1) looked away for 1 consecutive second after having looked for at least 5 (familiarization) or 6 (test) cumulative seconds, or (2) looked for a maximum of 20 cumulative seconds. Shorter maximum values were used in Experiment 4 because infants received two pairs (instead of one pair) of familiarization trials and because the test trials used a non-repeating procedure with a final paused scene.

5.2 RESULTS AND DISCUSSION

Analyses of infants’ looking times during the final phase of the test trial (Fig. 5) yielded a significant Condition X Trial interaction, $F(2, 45) = 4.85, p = .012$ (no such interaction was found in an analysis of infants’ averaged looking times during the final phases of the fur-can and box familiarization trials, $F(2, 48) < 1$). In the self-propelled condition, infants looked reliably longer if shown the fur-can as opposed to the box trial, $F(1, 45) = 16.08, p = .0002$; in the non-self-propelled and silent-control conditions, in contrast, infants looked about equally at either trial, both $F$s(1, 45) < 1. Thus, infants detected a violation when the fur-can produced a rattling
noise when shaken, but only if it was self-propelled. These results provide converging evidence that infants identify self-propelled furry objects as animals and expect their insides to be filled as opposed to hollow.
CHAPTER 6
GENERAL DISCUSSION

Together, these experiments indicate that 8-month-olds expect a novel object to have insides if they identify it as an animal. This identification may come about because the object gives evidence of autonomous motion and control, or because it presents cues with predictive validity for distinguishing animals from other objects. In either case, upon identifying the novel object as an animal, infants immediately expect it to have insides, in accordance with the innards principle. This expectation supports the biological hypothesis that infants already endow animals with biological properties.

At least two main questions remain concerning infants’ expectations about insides. First, do infants regard an animal’s insides as essential for its functioning? If infants witnessed the removal of the insides of a novel self-propelled agent, would they expect it to no longer be capable of autonomous motion and control? Second, how should we conceptualize infants’ expectations about insides? There are at least three possibilities. One is that these early expectations are part of a skeletal explanatory framework that underlies core biological reasoning (Opfer & Gelman, 2010). In this view, infants would possess a naïve theory of biology as well as naïve theories of physics and psychology, though their naïve theory of biology might be less rich. Another possibility is that infants’ expectations about insides reflect general biases or modes of construal that are not exclusively tailored for biological phenomena (Gelman, 2009; Keil, 1992). For example, abstract biases for teleology and essentialism, perhaps with sparse conceptual constraints, might lead infants to posit various internal features in order to explain objects’ capacity for self-propulsion (internal energy), for agency (internal states), and for both self-propulsion and agency (innards). Finally, a third possibility is that infants’ expectations about
insides arise from a quite different source—the cognitive systems that humans evolved to identify predators and preys and, more generally, to deal with animals as a food source (Barrett, 2005). One striking aspect of the present findings is that infants did not expect objects that were only self-propelled or only agentive to have insides; apparently, internal energy or internal states do not at first require physical substrates. In contrast, infants expected objects that were both self-propelled and agentive to have physical insides. This physical-substrate requirement seems consistent with an interpretive framework that regards animals primarily as food.

Whichever possibility turns out to be correct, it is clear that infants’ expectations about animals are highly primitive and that considerable conceptual elaboration and change must occur for young children to develop a more advanced understanding of biology. Nevertheless, the present research fits well with several developmental results. If infants construe animals as self-propelled agents with biological properties, then it makes sense that (1) young children initially have difficulty constructing a category of living thing that includes plants as well as animals (Carey, 1985); (2) young children who are taught that plants engage in self-propelled, agentive motion immediately infer that plants are living things (Opfer & Siegler, 2004); and (3) school-aged children and adults who see computer-animated blobs engage in self-propelled, agentive motion describe them as alive and attribute to them various biological properties (Opfer, 2002). All of these results suggest that key components of the interpretive framework that guides infants’ expectations about animals persist throughout life.
FIGURES

Familiarization Trials

a. Self-propelled/Agentive Condition
   Can Trial  Box Trial

b. Non-self-propelled/Non-agentive Condition
   Can Trial  Box Trial

c. Self-propelled/Non-agentive Condition
   Can Trial  Box Trial

d. Non-self-propelled/Agentive Condition
   Can Trial  Box Trial

Pretest Trials

e. Can Trial  Box Trial

Test Trials

f. Hollow Trial  Closed Trial

Figure 1. Schematic drawing of the events shown in Experiments 1 and 2. In Experiment 1, the can and box were either self-propelled and agentive (a) or neither self-propelled nor agentive (b). In Experiment 2, the can and box were self-propelled and agentive (a), self-propelled but non-agentive (c), or non-self-propelled but agentive (d). Whether the can trial or the box trial was shown first in the familiarization, pretest, and test trials was counterbalanced across infants in each condition; whether the can or the box was hollow in the test trials was also counterbalanced across infants in each condition.
Figure 2. Mean looking times of infants in Experiments 1-3 during the test trials as a function of condition and event. Errors bars represent standard errors, and an asterisk denotes a significant difference between the events within a condition ($p < .05$ or better).
Figure 3. Schematic drawing of the events shown in Experiment 3. Whether the fur-can trial or the box trial was shown first in the familiarization, pretest, and test trials was counterbalanced across infants in each condition.
Figure 4. Schematic drawing of the events shown in Experiment 4. Whether the fur-can trial or the box trial was shown first in the familiarization trials was counterbalanced across infants in each condition. In the test trial, infants saw either the fur-can or the box trial.
Figure 5. Mean looking times of infants in Experiment 4 during the final phase of the test trial as a function of condition and event. Errors bars represent standard errors, and an asterisk denotes a significant difference between the events within a condition ($p < .05$ or better).
REFERENCES


