INFANTS’ REASONING ABOUT ANIMALS

BY

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DISSERTATION

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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 reason about animals biologically. If there is a core biological domain, it may have its origins in infancy, and expectations about insides and animal behaviors are likely candidates for early biological expectations. First, I focus on animals’ insides and ask whether infants expect that the removal of an animal’s insides should lead to the loss of function, and more specifically the loss of self-propulsion (Experiment 1). Second, I am interested in whether infants know about behaviors that all animals share. I use an inductive over-hypothesis approach: if infants view certain animal behaviors as privileged, then small amounts of evidence that an animal of a kind engages in a specific behavior may lead to rapid generalization of the same behavior to the entire kind. Using this generalization method, I investigate infants’ expectations about two kind-specific behaviors of animals: having the same diet (Experiments 2-3) and producing the same sounds to communicate (Experiments 4-5). In Experiments 2 and 3, 15-month-olds expect animals of the same kind (as indicated by shape similarity) to share food preferences – a kind relevant property, but not the same toy preferences – a kind irrelevant property. These contrasting results suggest that infants did not simply expect similar objects to share similar non-obvious properties. Rather, their expectations were driven in part by a biological framework that views diet, but not toys, as biologically relevant. In Experiments 4 and 5, 15-month-olds expect animals of the same kind to make the same types of sounds, but do not have similar expectations for animals of two distinct kinds, or two similar shaped non-animal objects. These experiments thus provide converging evidence that self-propulsion and agency
(demonstrated by having a food preference or vocalizing contingently) together signal the
ontological status of animal, and that infants’ conceptual knowledge in turn guides their
reasoning and generalizations about animals’ biologically relevant behaviors. Positive evidence
in these experiments supports the biological hypothesis that infants may have a distinct
biological domain, and may immediately ascribe to entities identified as animals additional
properties that are biological in nature.
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CHAPTER 1

INTRODUCTION

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 reason about animals biologically.

Young children seem to know that there are different categories of things in the world and reason about them differently, using different causal principles. Knowing whether something is an animal or an artifact affects how we categorize it, interact with it, and expect it to behave. By elucidating young children’s ontological categories and causal-reasoning frameworks, we can understand how cognitive processes and causal reasoning develop and how they lay the ground for adult causal “theories”.

Research on how infants make sense of the world around them has focused on causal reasoning in three core domains: physical, psychological, and biological. Much of the discussion in the past decades has been focused on the first two – the domains of physics and psychology. Whether there is a domain of biology with its own causal-explanatory framework and principles is an issue of debate. For each causal framework, the key components of enquiry are how children identify entities within the domain, and if children’s reasoning about entities within the domain is informed by deeper causal relationships unique to the domain.

One issue without consensus is ontology – what entities within the domain should be studied and count as evidence of biological understanding. A mature conception of biology includes all living things such as animals and plants. The animate-inanimate distinction does not map onto a living/non-living distinction. Understanding that plants are living things just like
animals happens much later in development (Carey, 1985; Piaget, 1929; Richards & Siegler, 1986; Waxman, 2005). Adults and even college biology professors have more difficulty ascribing life to plants (Goldberg & Thompson-Schill, 2009). There is also evidence suggesting that reasoning about animals is domain-specific and can be selectively impaired in brain-damaged patients while reasoning about plants remains intact (Caramazza & Shelton, 1998).

In a cross-cultural study, Waxman (2005) tested 6-7 and 9-10-year-old urban, suburban and rural children from Chicago, Evanston, and the Menominee Nation in Wisconsin, respectively. In a sorting task, children were asked to sort cards with animals, plants, and artifacts on them into various categories such as “alive”, “die”, “grow”, and “need food”. For “die”, “grow” and “need food”, even the youngest children tested could correctly include all living things. Interestingly, it was the category “alive” that young children and urban 9-10 year-old children did not do well in. Waxman speculated that the concept of animal is “guided by a set of core principles that are available to young children and by naming practices” whereas the concept of alive is not.

Therefore, the animate-inanimate distinction, i.e., animals versus artifacts, has been suggested as a starting point for reasoning about biological kinds (e.g., Wellman & Gelman, 1992; for a review, see Gelman & Opfer, 2002). From this perspective, examining how young children reason about animals is thus a good place to begin looking for evidence for the presence of an early biological explanatory framework.

Another issue of disagreement concerns the causal framework that children use to reason about animals. Do infants possess abstract expectations about animals that could provide the foundations for the acquisition of more sophisticated biological knowledge? (biological as used here refers to living processes pertaining to life or those that are important for maintaining
There are two broad hypotheses concerning this issue; we refer to them as the “nonbiological” and the “biological” hypotheses. Proponents of both hypotheses agree that key components of infants’ concept of animal are likely to be notions of self-propulsion and agency. According to the non-biological hypothesis, for infants and toddlers animals are essentially self-propelled agents (“behaving beings”, “self-propelled interactants”). In contrast, the biological hypothesis leaves open to the possibility that there could be an early biological core domain in infancy, so that animals are not simply self-propelled agents but possess additional, biologically relevant properties.

In this chapter, I will first review background research on infants’ knowledge about self-propulsion, agency, and other animal-like features. Next, I will review the theoretical positions of investigators who propose a non-biological hypothesis, and then discuss the viewpoints of those who propose a biological hypothesis. Finally, to explore what might be candidate biological expectations in infancy, I will review research with preschoolers focusing on two candidate properties: animals’ insides, and animals’ biologically relevant behaviors. The experiments reported in this thesis built on this research.

1.1 Background Research

1.1.1 Biological motion and self-propulsion

Animals move in a non-rigid, patterned manner and the ability to detect animal-like motion is useful in identifying animals. Sensitivity to the biological motions of point-light displays has been shown to be present in humans and animals from birth (e.g., Bardi, Regolin, & Simion, 2014; Bertenthal, 1993; Simion, Regolin, & Bulf, 2008; Vallortigara, Regolin, & Marconato, 2005). Thus the ability to discriminate and preferentially attend to other animals appears to be inbuilt and non species-specific.
In addition to studying infants’ responses to biological motion, infant researchers have also examined their responses to self-propulsion (often involving non-biological motion, such as an object moving rigidly back and forth). In general, this research suggests that when a novel object gives evidence that it is capable of autonomous motion (e.g., begins to move on its own), even young 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).

1.1.2 Agency

How do infants identify agents? Research has found that agents need not be human (e.g., Johnson, Booth, & O’Hearn, 2001; Luo & Baillargeon, 2005; Luo, 2011) or have identifiable features such as faces with eyes (Csibra, 2008; Gergely & Csibra, 2003; Johnson, Slaughter, & Carey, 1998). An entity can demonstrate its agency by engaging in behaviors such as selecting goals or responding contingently, giving evidence of internal control. 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).

Luo (2011) replicated the results of Luo and Baillargeon (2005) and found that even 3-month-olds can reason about a novel box as an agent. In the experiment, a novel self-propelled box demonstrated a preference for a cone as opposed to a cylinder by choosing to contact it repeatedly during familiarization trials. When the positions of the cone and cylinder were switched in test as per the Woodward (1998) paradigm, infants expected the box to contact the cone in its new position and were surprised if it contacted the cylinder. In the control condition
there was only one object during familiarization. Therefore although the box contacted the cone, it was not necessarily indicating a preference, since there was only one object present; infants therefore held no clear expectations about the box’s preference during test trials. The next experiment tested another way to induce preference even with one object in familiarization. The cone alternated between being located on the left and the right of the stage in the familiarization trials and the box always approached it, demonstrating equifinality. In test trials, infants once again expected the box to approach the cone and were surprised if it approached the cylinder.

Csibra (2008) found similar results by showing 6.5-month-old infants video clips of a self-propelled box. Infants were willing to attribute a goal to the box if it varied its route, taking efficient paths to reach its destination. Hence, the ability to vary one’s behavior in a rational manner is an important cue for agency.

Shimizu and Johnson (2004) tested 12-month-old infants with a green blob following Woodward (1998) paradigm. A green blob demonstrated agency in the agent condition by turning to face the experimenter, beeping contingently in response to the experimenter’s ‘conversation’ with it. In contrast, in the non-agent condition, the blob never turned to face the experimenter or the choice object before approaching it, i.e., it travels in a simple trajectory, and it beeped non-contingently while the experimenter remained silent. In both conditions the blob went towards a choice object and contacted it in habituation trials. In the test trials, infants expected the agent blob to approach the same target in a different location and were surprised when it did not. Infants who saw the non-agent blob had no such expectations. Johnson, Shimizu and Ok (2007) followed up with experiments and found that for 12-month-old infants, one of the cues (interacting contingently with an experimenter or aligning itself with the target before approaching it) was enough to determine agency.
Csibra, Gergely, Biró, Koós, & Brockbank (1999) found that for 9- and 12-month-olds, self-propulsion was neither sufficient nor necessary to interpreting an agent as goal-directed or rational. Infants habituated to a small circle that looks like it could have conceivably be thrown over an obstacle towards a larger circle target, and in test, infants dishabituated to the small circle taking the longer same path (old action test event) when there was no obstacle in its place, compared to when it took a shorter straight-line path towards its target (new action event). This suggests that when the events could be interpreted as a case of rational goal-approach, infants inferred that the small circle should adjust its path and approach its goal via a direct pathway, when there was no obstacle. This result was true even when the small circle did not exhibit cues of agency such as self-propulsion, irregular path of movement, or non-rigid transformation of its surface. Csibra et al.’s (1999) experiment demonstrated that there could be inert agents, and that physical and psychological principles of self-propulsion and agency can be separate and independent of each other.

Taken together, it appears that infants attribute agency to non-human as well as human agents, based on a variety of cues including the choice of a goal object, the choice of means to a target, and contingent responding (e.g., Csibra, 2008; Johnson, Shimizu & Ok, 2007; Luo, 2011; Luo & Baillargeon, 2005; Shimizu & Johnson, 2004; Tremoulet & Feldman, 2000). Research suggests that self-propulsion and agency are distinct concepts, self-propulsion is not sufficient for agency, as self-propelled objects are still not viewed as agents and do not automatically elicit attributions of intention (it did not work for Johnson, Shimizu & Ok’s blob nor Luo & Baillargeon’s box in the control condition). As the studies reviewed have shown, self-propelled objects could be non-agentive, and agents can be non-self-propelled.
1.1.3 Other cues for identifying animals

Young children may begin with the knowledge of self-propulsion and agency in their identification of animates or animals and build on this knowledge as they learn more about animals. With experience, young children learn about other properties of animals, such as their shapes, surface textures, the presence of body parts such a face or wings, and their behaviors. Subsequently, animals could be identified by other properties, for example, the presence of self-propulsion and fur (Setoh, Wu, Baillargeon, & Gelman, 2013). There are numerous properties related to animals, I will review three of them; shape, fur, and facial features.

*Shape.* Shape is a potent cue to the identity of an object and object categories. Examination of children’s inductive inferences allows us to find out whether they believe that the objects belong to the same category or kind (Carey, 1985; Gelman & Markman, 1986). There is a huge shape bias and shape generalization literature (e.g., Booth, Waxman, & Huang, 2005; Graham, Kilbreath, & Welder, 2004; Graham & Kilbreath, 2007; Graham & Diesendruck, 2010; Jones & Smith, 1998; Landau, Smith, & Jones, 1992; Landau, Smith, & Jones, 1998). The general finding is that children exhibit a shape bias when both extending a novel label and when categorizing objects, suggesting that shape is used to group conceptual kinds together. Hence shape may indicate category membership for functional kinds and animal kinds.

In a replication and follow up study of Markson and Spelke (2006), Shutts, Markson, and Spelke (2009) examined how 7-month-olds generalize autonomous motion of animals versus artifacts. During familiarization, infants were presented a pair of animals that differed in shape only (e.g., blue crab and blue horse), and one of them moved on its own while the other was moved by a hand. For the test trials, infants viewed new objects presented without motion of the same shape but different color. They predicted that if infants differentiated between animals and
artifacts, and generalized self-initiated motion to animals, they will look longer at the animal shape of a different color that showed movement in familiarization trials. And this was what they found. Infants prefered looking at the object that shared the same shape as the one which exhibited autonomous movement previously. Next, Shutts et al. (2009) suggested that “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.” (p. 202). However, this hypothesis was not supported by the data. When shown a blue crab and a tan crab in familiarization, one of which demonstrated self-initiated motion whereas the other was moved by hand, 7-month-old infants did not generalize the expectation that the same color will move when shown a blue horse and a tan horse in test. In addition, when shown the same blue crab and tan crab in test, infants looked equally at them too, suggesting that they had no expectations about movements of crab-shaped objects. Perhaps with two conflicting exemplars, one crab shape which moves on its own and one which does not, infants did not form an expectation about the motion of crab-shaped objects. It is a strong proposition that color indicates similar material composition and a common structure. People have different color skins but are made of the same material. Dogs and cats have fur in a variety of shades with different patterns on them. Perhaps infants generalize more conservatively. Compared to color, shape is a more reliable indicator of category membership.

**Fur.** Fur is a secondary cue that infants may learn to associate with being an animal. In a clever study of infants’ motion expectations for animal-artifact categories, Pauen & Träuble (2009) investigated how 7-month-old infants interpreted an ambiguous event where a ball and a furry animal toy with a face moved together in a self-propelled, irregular manner. During the test
trial, infants looked longer at the toy animal when both objects sat motionless in separate locations, suggesting that they attributed the self-initiated motion to the furry animal toy but not to the ball, and perhaps looked longer at it because they anticipate its future actions. Follow-up experiments found that both the facial features and the furry body were necessary for inference of animacy – if one of the features was removed, infants did not exhibit clear expectations of future motions to it; they looked longer at the ball when the furry animal had no facial features and looked equally at both objects when the animal had a non-furry, hollow spiral body with a face.

*Face and eyes.* Having a face, and especially eyes is another cue to animacy and agency. Human newborns were able to follow eye gaze of a schematic face (Farroni, Massaccesi, Pividori, & Johnson, 2004) and newly hatched chicks were able use the gaze of an artificial face to rejoin their imprinted ball object faster (Agrillo, Regolin & Vallortigara, 2004). 3-month-old infants attend to shifts in adult eye gaze as well (Hood, Willen, & Driver, 1998). Johnson, Slaughter and Carey (1998) demonstrated that 12-month-old infants would follow the ‘gaze’ of a novel brown asymmetrical object covered in faux fur when it had a face, or engaged in contingent exchanges with an experimenter, and also when it exhibited both cues. Without either of the cues of facial features and contingent responding, infants did not follow the object’s ‘gaze’.

However, tacking eyes on an object does not automatically make it an animal. As Booth, Waxman & Huang (2005) pointed out, “eyes (and shoes) play an important part in word extension, because they each signal the ontological status of the object being named (i.e., animacy). This conceptual knowledge of animacy then guides attention to the most relevant object properties” (p. 493). Inductive inference studies such as Welder and Graham’s (2006) capitalize on this by getting 15-month-old infants to pay attention to less obvious parts of objects.
with eyes on them compared to those without eyes. The combination of cues such as having face or eyes probably fall along a continuum, just the motion of an entity might range from being biologically artificial to naturalistic, and it may turn out that some features are more privileged than others, for instance, eyes being a better cue than fur or feathers.

*Generalizing information across animals.* All of the above information can be used not only to identify animals but also to generalize information across animals. For example, Mandler and McDonough (1996, 1998) found that 14-month-olds have different expectations for the behaviors of animals and artifacts. After an experimenter modeled an animal domain-appropriate action (e.g., drinking) on a target object (e.g., a dog), infants were more likely to imitate that action on another novel object from the same target domain (e.g., a cat), than that from the artifact domain (e.g., car). Similarly, after an experimenter modeled an artifact domain-appropriate action (e.g., starting with a key) on a target object (e.g., a car), infants were more likely to imitate that action on another novel object from the same target domain (e.g., a truck), than a novel object from a different domain (e.g., a bird). This experimental method allowed infants to demonstrate inferences about a domain which they knew about.

1.2 The Non-Biological and Biological Hypotheses

Proponents of the non-biological and biological hypotheses are likely to agree with non-biological perspective that i) the concept of an animal involves self-propulsion and agency, ii) young children learn with experience more biological properties beyond self-propulsion and agency, and iii) all the information learnt about animals can be used to identify animals, and to reason and generalize their behaviors. Where the two perspectives differ in the hypothesized beginning point. Advocates of the non-biological view typically assume that there is no early, autonomous domain of biology; biological reasoning about animals does not emerge until age 4
or 5 or later. In contrast, proponents of the biological view are open to the possibility that a distinct biological domain is in place earlier, before 3 years of age, and that reasoning with the biological domain brings about additional expectations beyond physical and psychological concepts.

1.2.1 Non-biological hypothesis: Animal = Self-propelled + Agentive

According to the non-biological hypothesis, infants do not endow animals with vitalistic or biological properties: animals are simply entities that are self-propelled and agentive (these two properties are conceptually distinct (Baillargeon, Wu, Yuan, Li, & Luo, 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 views on how infants come to understand self-propulsion and agency. According to some views (core-domain and perhaps vitalistic-causality view), self-propulsion and agency are part of the core explanatory frameworks that underlie naïve physics and naïve psychology, respectively. According to other views (image-schema and association-learning views), self-propulsion and agency come to be understood via domain-general mechanisms. Each view is discussed in more detail below.

1.2.2 Core-domain view

According to the core-domain view (Carey, 1985, 1988, 2000), infants’ concept of self-propulsion is part of the skeletal explanatory framework that underlies core physical reasoning, whereas infants’ concept of agency is part of the skeletal explanatory framework that underlies core psychological reasoning. Carey argued that children lack any understanding of the mechanisms underlying biological processes and thus do not possess an autonomous domain of
biology before age 10, which was later revised down to age 7 or 8 (Carey, 1995, 2000; Carey & Spelke, 1996).

Infants’ and preschoolers’ concept of an animal starts as a behaving being, a simplified version of people, the prototypical behaving being, and animals’ behaviors are generally understood in terms of desires and beliefs (Carey, 1988, 2000). Children misconstrue biological processes by inappropriately interpreting them within a psychological framework. For example, eating may be understood as serving to fulfill an animal’s desire to eat (psychological) so as to assuage its hunger, and not understood in terms of nutrition or nourishment that is necessary for an animal to maintain life functions. As preschoolers learn more about animals, their knowledge about animals is a collection of facts that is not integrated or organized in any causal framework. Only later in development do children acquire knowledge about specific organs and their functions, organized around core concepts of life cycles and maintaining life rather than supporting behavior, from which children can form further inductions about other unknown biological properties.

Biological reasoning in the core-domain view has a wider definition and encompasses all living things, including plants, and goes beyond the animate-inanimate distinction. Only by 7 or 8 years of age, with the restructuring of concepts, do children begin to construct an intuitive framework of biology that combines plants and animals as living things and is organized around core biological principles, such as life cycles and functions related to the maintenance of life and not just supporting behaviors (Carey & Spelke, 1996; Carey, 2000).

1.2.3 Vitalistic-causality view

Hatano and Inagaki propose that by the end of the preschool years, children possess an intermediate form of causality between psychological and mechanistic causality, termed
‘vitalistic causality’ (Hatano & Inagaki, 1994; Inagaki & Hatano, 1993). Vitalistic causality personifies the internal organs, where target phenomena are caused by their activity, giving them an ‘agency’ or vital power. Vitalistic causality is different from person-intention causality in the sense that it is non-intentional; it is the organ’s activities that induce the phenomenon independent of the person’s intention.

Inagaki and colleagues used an induction paradigm and found that young children base their explanations about unfamiliar properties of a target object on their similarity to humans. Since the children they interviewed only applied such reasoning within the biological domain and not for artifacts, it reflects an autonomous biology according to the vitalistic causality view (whereas it is thought to reflect reasoning from a psychology framework in the core domain view). Although young children’s biology is qualitatively different from older children’s and adults’, the maturation of their biological knowledge remains a change within autonomous biology.

Hatano and Inagaki’s framework of autonomous biology includes both plants and animals within the category of living things, and so they conducted interviews with preschoolers to find commonalities in their reasoning about plants and animals. They have found that when provided a biological context, 5-year-olds can appropriately generalize essential biological properties such as growing, needing food and water, and being ill from humans to plants, thus showing evidence that preschoolers can consider both animals and plants as biological entities with the same underlying causal mechanism (Inagaki & Hatano, 1996).

Although Inagaki and Hatano’s content-rich theory of vitalistic causality could be seen as an initial core that makes folk biology domain specific from the beginning (Keil, 1994), they leave open to speculation whether or how early biological reasoning might be present, as they
have not examined younger subjects. They propose that acquisition of biology “comes a little later than that of physics or psychology” (Hatano & Inagaki, 2000, p. 180), and “it is still debatable whether three-year-olds have biological domain of thought – more specifically, whether they possess a uniquely biological mode of reasoning” (Hatano & Inagaki, 2000, p. 270).

1.2.4 Image-schema view

The image-schema view (Mandler, 2012) assumes that infants’ concepts of self-propulsion and agency are formed by a domain-general perceptual-meaning-analysis mechanism that re-describes spatiotemporal information into meaningful iconic representations, i.e., the conceptual system starts out as a spatial system. Infants in the first year of life have rich concepts for animates and inanimates because they develop knowledge about their motions through perceptual analysis. Perception is translated into concepts when image schemas are formed of spatial structure of motion events.

Animals can be conceptually differentiated on the basis of a few primitives. According to the image-schema view, concepts of goal and agency are based on behaviors and not intention, so those characterizations are enough to account for 5-to 6-month-old infants’ reasoning about animals. The concept of animal, which includes birds, fish, mammals, and so on, is not innate. The animal category is formed based on infants’ observations of self-moving agents by 7 to 9 months. “Indeed, forming a concept of animal as a self-moving interactor depends on extracting the same information from perception of a variety of different animals’ behavior” (2010, p. 32).

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. As infants acquire conceptual knowledge of animates and their motion properties, they generalize the two concepts in both directions – agency to self-propelled objects and self-propulsion to agents, because their knowledge that animates are agents engaged in causal events is embedded within the same conceptual representation of animacy. This differs from the biological hypothesis’ skeletal causal principle perspective (e.g., Baillargeon et al., 2009; Gelman, Durgin, & Kaufman, 1995; Luo, Kaufman, & Baillargeon, 2009; Setoh et al., 2013) and other findings (Kuhlmeier, Wynn, & Bloom, 2004) which proposes that agency and self-propulsion are independent concepts; infants assume objects to be inert unless given unambiguous evidence that they are self-propelled, and infants assume agents to be inert unless given evidence otherwise, hence there is no cross generalization between agency and self-propulsion.

A spatiotemporal, behavior-based conceptualization of animals does not account for how young children are able to make causal attributions, which requires an understanding of intentions and agency (Carey, 2000). Other theorists point out that although animals are defined as self-moving interactors, it is not clear how, without a causal framework or concepts, a domain-general perceptual-analysis mechanism is motivated to make a distinction between internally or externally caused motion events to produce a “moves on its own” and “caused to move” schema that differentiates animates from inanimate (Subrahmanyam, Gelman, & Lafosse, 2002).

1.2.5 The association-learning view

Another perceptually-based non-biological view assumes that infants’ concepts of self-propulsion and agency are due to associations of perceptual elements. Infants pay attention to self-propelled objects and learn about their properties using domain-general learning
mechanisms that encode statistical regularities (Quinn & Eimas, 1997, 2000; Rakison & Lupyan, 2008). Perceptual appearance is important in picking out animates (i.e., people, animals, insects) from inanimates (e.g., vehicles, furniture, plants, and tools). Rakison and colleagues propose that the concept of animacy in infancy is rooted in self-propelled motion, causal actions, contingent interaction, agency, goal-directedness and intentional mental states – all of which can be extracted from information available in the perceptual input (Rakison & Poulin-Dubois, 2001). Infants identify functional parts such as legs and wheels and use them to distinguish animals from artifacts (Rakison, 2006). At about 14 months of age infants form elementary connections between dynamic features of animacy cues, so that when infants perceive an object possessing a particular part associated with animates, it will cue retrieval of causal properties associated with the part (Rakison & Poulin-Dubois, 2001). In line with association-learning proposals, there is continuity in the formation of biological knowledge, in the sense that it is an accumulation of connections that infants learn and remember about the world, and the strength of representation for causal agency and self-propulsion is based on the amount of visual evidence infants have had viewing such events (Rakison & Lupyan, 2008).

In the association-learning view, learning happens on the basis of correlations among perceptual features, regardless of which domain it might belong to, whereas the perceptual-schema view predicts that learning may differ across different conceptual domains. The association-learning view also differs from the perceptual-schema view in that generalization of agency and self-propulsion might be asymmetric, infants will be more likely to generalize the property of self-propulsion to agents because they see more exemplars of agency than self-movement in their world, and only later generalize agency to self-propelled objects (Cicchino, Aslin, & Rakison, 2011).
1.2.6 The Biological hypothesis: Animal = Self-propelled + Agentive + Biological properties

The biological hypothesis suggests that infants may have a distinct biological domain, and may immediately ascribe to entities identified as animals additional properties that are biological in nature.

1.2.7 Skeletal framework

Keil (1979, 1992) argues that the animate-inanimate distinction is one of the core ontological distinctions that is firmly established and innately constrained. He also proposes that ‘explicit understandings of biology may be shallower than they appear while implicit understandings may be richer” (Keil, 2003, p. 376), such that young children can sense abstract causal relations that are specific to biology before they can grasp the mechanisms behind them (Simons & Keil, 1995). With these domain-specific causal principles, “(k)nowing a particular property of a living kind allows one to make very different, and usually more powerful, inductions than knowing a property of an artifact” (Keil, 2003, p. 371). Keil and his colleagues suggest that when the appropriate biological context is not provided, young children will default to psychological explanations, and appear as if they lack biological concepts (Erickson, Keil, & Lockhart, 2010).

R. Gelman (1990) proposed that infants possess skeletal sets of domain-specific principles that define the entities involved and the operations the entities engage in. These causal principles identify relevant inputs and structure them accordingly, directing infants’ attention and organizing their learning of concepts within the domain. In this way, knowledge acquisition is both a function of these domain-specific principles and domain-general learning mechanisms that abstract information such as patterns of movement. This view is not content-rich but with the principles in place, children can rapidly learn about the animate-inanimate distinction, such that
by 3- and 4- years of age, preschoolers display remarkably accurate knowledge about the ways in which persons differ from inanimate objects (rocks and dolls), for example with respect to actions, parts, mental states, and reciprocal actions (e.g., talking to one another) (Gelman, Spelke, & Meck, 1983).

S. Gelman and colleagues argue that children have a domain of biological thought that is distinct from physical or psychological thought and it starts from the core distinction of animate versus inanimate objects (Gelman & Wellman, 1991; Gottfried & Gelman, 2005; Wellman & Gelman, 1992). Gelman (1997) has suggested that the concept of “kind” emerges early in development, is domain-specific (used for animals and people more than for artifacts), and is in place by 2 years of age. Children’s framework of biology develop as they learn more about parts of animals, and acquire an understanding of how the mechanisms of insides are linked to behaviors (e.g., how insides cause an animal to grow) (Gottfried & Gelman, 2005).

1.3 Biological expectations in preschool: Understanding of animals’ insides and behaviors

If there is a core biological domain, what are some of the expectations about animals that might emerge early in life? One way to address this question is to examine what biological expectations young preschoolers possess about animals. In this section, I will focus on two sets of expectations: one concerns animals’ insides, and the other concerns animal behaviors relevant to maintaining life or function, such as eating, digesting, breathing, regulating temperature, reproducing, growing, and communicating.
1.3.1 Insides

R. Gelman (1990) proposed 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). 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. Gelman (1987) also found that 3-year-old children knew that animate and inanimate objects had different insides, reporting that animates had food, blood, bones, and internal organs inside, whereas inanimates have either nothing, ‘hard stuff’, cotton, or paper. Carey (1982) reported that 4-year-old children were more willing to attribute internal organs (“spleen”) to animals (e.g., worm) rather than inanimate objects (e.g., mechanical monkey), despite the superficial similarity of the monkey to a person than a worm to a person, and children’s ignorance of internal organs such as spleens. Children’s conceptual understanding appear to guide their inductions such that they were able to switch their answers according to the conceptual category the item belongs to. 4- and 5-year-old children reported that animate objects have animate “innards” (blood and bones) and animate externals (wings and eyes), whereas inanimate objects have inanimate parts and materials (plastic and glass) for their insides and outsides (Subrahmanyam et al., 2002).

Gelman and Wellman (1991) conducted a study similar to Keil (1989), but with simpler transformations. Using three classes of objects, each object either had its insides or outsides removed. For two classes of objects, their insides are more important to their identity, e.g., for a dog, its blood is more important than its fur, and for a car, its engine is more important than its
paint. Another class of container-like objects served as control; e.g., for a jar, its insides are not requisite to its identity. For each object, 4- and 5-year-olds were told about three transformations: the removal of insides, the removal of outsides, and movement (as a control); children were asked about the object’s identity and function after each transformation. The preschoolers did well on the task, correctly reporting that the identity of containers would not change when their contents were removed, and that the identity and function of the insides-essential items would change when their insides were removed but not when their outsides were removed, even if their appearance changed drastically. Thus by age 4, children expected category members to have similar insides, and they knew that animals cannot function properly without insides. Similarly, Gelman and O’Reilly (1988) found that 4-year-old children assumed that members of the same category have the same inside parts and substance.

In a determined effort to find out if children knew how the insides of animals and machines really looked like, Simons and Keil (1995) first tested children with clip-art drawings of animal-insides and machine-insides superimposed on pictures of animals and machines. They asked children, “Which shows a real sheep with real sheep insides?” Few 3- and 4-year-olds responded above chance level. The authors then went a step further towards realism and replaced the drawings with photographs of real insides of a fetal pig, a large tool shop, and aggregate substances like a pile of rocks. 3- and 4-year-olds did not do well on the task but 8-year-olds responded accurately. In the next experiment children were presented with glass jars containing real preserved insides of cats and machine parts like dials and gears, and small rocks suspended in gelatin. 4-year-olds did not perform better; only half matched the correct patterns. Emphasizing the roles and functions of insides in subsequent experiments did not improve their performance either. Overall, children in the study expected insides of animals and machines to
differ; they consistently picked different insides for animals (natural kinds like rocks or animal insides) and machines (machine insides or blocks), but did not display clear expectations about the exact appearance of animal and machine insides.

In Gottfried and Gelman’s (2005) task, 4-year-old children displayed clear expectations for kinds of insides for plants, animals and machines. Children were shown pictures of unfamiliar animals, plants and machines. They were first asked to provide spontaneous answers to “What is inside this animal/ plant/ machine?,” then asked a true/false choice question verbally or pictorially by a puppet (there were pictures of one plant part, one animal part, one machine part for children to choose from). 4-and 5-year-olds performed equally well whether on verbal or pictorial task, and did less well when the questions involved plants. The authors suggested that the stimuli used in Simons and Keil (1995) were too strange, which explains why they only found different expectations of insides much later. It could also be that providing the taxonomic classification of “animal” and “plant”, contrasted with “machine” helped 4-year-olds to categorize and tap into their representations of animal/ plant/ machine better than naming the specific animal (“sheep”) in the Simons and Keil (1995) tasks.

1.3.2 Inductions concerning biologically relevant behaviors

Natural kinds have rich correlated structures, including nonobvious similarities, that are not easily identified by perceptual similarities (Gelman, 2000; Gelman & Markman, 1986). Natural kinds are categories with rich inductive potential, and inductive inferences go beyond what is obvious or could be known with logical certainty. S. Gelman and colleagues’ “category-based induction” experimental paradigm has been fruitful in studying the inferences that children and adults make in extending hidden, unobservable properties from one category member to another (Gelman, 2000). How children make inferences gives insight into what entities they
group as belonging to the same kind, and which properties they are willing to extend from one category member to another.

Preschoolers are able to draw rich inferences from labels of natural kinds, even when instances appear very different on the surface, and there is only the label that categorizes them as the same thing. In a series of clever experiments examining children’s inductive inferences, Gelman and Markman (1986) presented 3- and 4-year-old children with a triad task, in which the stimuli consisted of two items and one target test picture. The triad task was designed to pit perceptual similarity against category membership. For example, one of the items was a “squirrel” (gray squirrel), and the other was a “rabbit” (brown rabbit), and children were told a hidden property about the two items; the squirrel eats bugs and the rabbit eats grass. The target item was labeled a squirrel but looked like a rabbit (kaibab). The task was to generalize the hidden property to the test item, “See this squirrel? Does it eat bugs, like this squirrel, or does it eat grass, like this rabbit?”. In general, children were more likely to generalize properties from same label items than from similar appearance items. Children inferred that the kaibab eats bugs just like the squirrel even though they look very different and it resembles a rabbit.

Gelman and Markman (1987) subsequently investigated how 3- and 4-year-old children made inductive inferences given one newly learned property of a target; half of the targets were animals, the other half inanimate objects (e.g., shell, salt, oil). For example, children were told a nonobvious property that a small blue bird gives its baby mashed-up food (“See this bird? This bird gives its baby mashed-up food.”), then they were tested about that property with four test pictures - a small blue bird in a different pose (same category, similar appearance), a blackbird (same category, different appearance), a blue butterfly (different category, similar appearance), and a dog (different category, different appearance), presented one at a time in random order. For
each of the pictures, the experimenter placed the picture directly below the target and said, “This one’s an X (where X is the label, e.g., bird). See this X? Do you think it feeds its baby mashed-up food, like this bird?” Results from 3-year-old children were similar to that of the 4-year-olds. Overall, children based their answers more on category membership. Children were more likely to infer that birds feeds their baby mash-up food, even when the bird looked different from the target. Children based their inferences more on category membership for the animal category, and more on appearances for inanimates. An interesting finding was that in the condition where labels were not provided, children were still able to draw category-based inferences when the pictures contained sufficient cues to detect category membership (e.g., from a green leaf insect to a black beetle, probably because they both have eyes, feet, and antennae; whereas despite a leaf’s striking similarity to a leaf insect, it lacked characteristic animal features such as limbs and face).

1.4 The Present Research: Understanding of animals’ insides and behaviors in infancy

As we saw in the last section, preschoolers expect animals to have insides, they realize that animals cannot function properly without their insides, and they also have some expectations that animal insides are different from artifact insides. Preschoolers are also able to use the animal kind category to make inferences about novel properties and behaviors of animals. In my studies, I examine if there are earlier precursors to these abilities; if there is a core biological domain, it may have its origins in infancy, and expectations about insides and animal behaviors are likely candidates for early biological expectations.

First, I focus on animals’ insides and ask whether infants expect that the removal of an animal’s insides should lead to the loss of function, and more specifically the loss of self-propulsion and agency (Experiment 1). Second, I am interested in whether infants know about behaviors that all animals share. However, this is difficult to study experimentally (i.e., the
absence of a behavior does not mean that a behavior is absent, as the behavior could occur at irregular intervals). Hence, I use an inductive over-hypothesis approach instead: if infants view certain animal behaviors as privileged, then small amounts of evidence that an animal of a kind engages in a specific behavior may lead to rapid generalization of the same behavior to the entire kind (e.g., if infants see that one rabbit likes to eat carrots, will they generalize this behavior to all rabbits?). Using this generalization method, I investigate infants’ expectations about two kind-specific behaviors of animals: having the same diet (Experiments 2-3) and producing the same sounds to communicate (Experiments 4-5).

Positive evidence in these experiments would support the biological hypothesis that infants may have a distinct biological domain, and may immediately ascribe to entities identified as animals additional properties that are biological in nature.
CHAPTER 2

REMOVAL OF INSIDES

Preschoolers expect animals to have insides (Gelman, 1990) and expect these insides to be different from those of artifacts (Gottfried & Gelman, 2005; Simons & Keil, 1995). 4- to 5-year-olds know that the insides of an animal are needed for its functioning, and report that a dog will not be able to bark if its insides was removed (Gelman & Wellman, 1991). However, when interviewed about animal vocalizations after the removal of the brain or after a brain transplant, 3-6-year-olds think that a dog will still bark even in the absence of a brain, and did not think that a transplant will change an animal’s characteristic sound (it was found that adults did not consistently think so too) (Gottfried, Gelman & Schultz, 2005). It could be the internal organs’ activity give rise to behavior (Inagaki & Hatano, 1993, 2004), but it could also be a vital energy independent of internal parts (Morris, Taplin, & Gelman, 2000) that provides an animal with its life force. Keil (2003) goes further, proposing that “(g)uts, innards, and other internal processes seem to play only a minimal role in their reasoning” (p. 374). Do infants know that insides are necessary for maintenance of function and life for animals but not always necessary for artifacts? For artifacts, a toy with its batteries taken out or a radio with its insides taken out will not function, but a microwave and a refrigerator functions even though it looks largely hollow, and a tin robot wind-up toy walks after its wound even though it has largely hollow insides.

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 (Newman et al., 2008).

In a test of the biological hypothesis, Setoh et al. (2013) found that when a novel object gives evidence that it is capable of both autonomous motion and control, 8-month-olds identify it as an animal and immediately expect it to have insides, in accordance with the innards principle. When the novel object lacks self-propulsion or social contingency, infants had no expectations of filled interiors. In the next series of experiments, 8-month-olds expect self-propelled furry objects to have filled interiors, but not objects that lacked one or both of the properties of self-propulsion and furrieness, and this was true whether the objects were shown to be hollow visually or if it rattles when shaken as though mostly hollow. Without much experience of animals’ insides, young infants inferred that the novel animals they were seeing for the first time should not be hollow, and that inert agents and self-propelled objects can be. Having insides is a non-obvious, hidden property true of all animals that could not be easily learned or observed at 8 months of age. These results provided direct support for the biological hypothesis by demonstrating that young infants possess abstract biological expectations about animals. In Pauen and Träuble’s (2009) study, 7-month-old infants did not expect an animal toy to be capable of self-propelled movement if it had a spiral body instead of a furry one. When the animal toy was self-propelled and furry, infants viewed it as an animal and expected future motion from it, but when it is self-propelled and not furry, they did not view it as an animal, and appeared not to expect it to move again.

My first experiment build on Setoh et al.’s (2013) results and ask whether young infants know that an animal’s insides are important for its behavior. Specifically, I investigate if infants have a more specific inkling of biological mechanisms and link animals’ physical insides to
behavioral outcomes. Do infants think that insides are important for animals’ self-propulsion and agency? In this study of causality and expectations for animals, I use novel animal displays from Setoh et al. (2013) to eliminate confounds of experience, and to distill the rules that a core biology domain might have about animals’ properties and behaviors. By guiding infants to categorize objects as animals by the animals’ behavior, I test whether infants expect animals to still maintain their functions of self-propulsion or contingent responding if they are shown that the animals’ insides are removed. (I also test that if the objects are not categorized as animals, i.e., they lack either self-propulsion or contingent responding, infants may not have expectations regarding function if the objects’ insides are removed.)

**Design**

In Experiment 1, infants are shown events involving two animals. First, animal A moves on its own and then another animal B moves on its own (i.e., they are both self-propelled). Then animal A responds contingently in conversation with the experimenter by making a particular kind of sound, e.g., quacking, and then animal B also responds contingently with the experimenter by beeping (i.e., they are agentive). Next, the experimenter removes all the insides of either animal A or animal B. In the test trials, animal A moves on its own, and animal B moves on its own too. If infants are reasoning about the animals within a biological framework, and think that insides are needed for an animal to move on its own, their expectations will be violated when the animal without insides still has the ability to move on its own.

**2.1 Experiment 1**

Do infants expect that the removal of an animal’s insides will affect its capacity for self-propulsion? In Experiment 1, 8-month-olds will be shown 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 are assigned to a *self-propelled/agentive* condition or a *self-propelled/non-agentive* condition. All infants will receive two motion-familiarization trials, two sound-familiarization trials, two pretest trials, and two test trials, one with the can and one with the box; half the infants will receive the can trial first in each pair of trials, and half will receive the box trial first. Only the sound-familiarization trials differ between the two conditions. Each trial has an initial phase and a final phase; looking times during the two phases are computed separately. At the beginning of the initial phase of the can motion-familiarization trial in the self-propelled/agentive condition (Fig. 1a), the can rests at the center of the apparatus floor. To start, the can moves in a slight bouncing manner back and forth across the floor and then returns to its original position (this displacement lasts 16s and serve to establish that the can was self-propelled; Luo et al., 2009). During the final phase of the trial, the can rests at the center of the apparatus, and infants watch this paused scene until the trial ends. The box motion-familiarization trial is identical except that the box moves in a slight zigzag manner. During the initial phase of the can sound-familiarization trial, a female experimenter opens a window in the back wall of the apparatus (4s), pauses (3s), and the can initiates a “conversation” by quacking at the experimenter, who responds contingently (this exchange lasts about 49s and serves to demonstrate that the can is agentive; Johnson et al., 2007). Finally, the experimenter leaves, closing her window behind her (2s). During the final phase of the trial, the animal rests at the center of the apparatus, and infants watch this paused scene until the trial ends. The box sound-familiarization trial is the same except that the box beeps at the experimenter. Infants in the self-propelled/non-agentive condition will receive similar familiarization trials except that the experimenter remains silent (thus providing no evidence that that they are agentive; Shimizu & Johnson, 2004).
Next, all infants receive the can and box pretest trials, which involve the removal of one of the objects’ insides and thus serve to provide context for the interpretation of the test trials. One of the pretest trials is an emptying event, where the experimenter empties out the insides of one of the animals, and the other pretest trial is an orienting event, where the experimenter simply rotates the animal to show infants its (closed) underside. In the initial phase of the emptying pretest trial (49s), the experimenter turns the can or box over, cuts around its bottom surface with a knife, removes its cover, removes two clumps of insides by first putting her hands into the can or box, wiggling her fingers within as if scraping at its interior wall, then removes the clump of insides and places them into a clear bowl. Next, the experimenter shows the infant that the can or box is hollow, rotates it and places it down on its open side (so that it looks the same as pre-surgery), and takes the knife, bottom surface, insides and bowl away. During the final phase of the emptying pretest trial, the animal stands in the center of the apparatus and infants watch this paused scene until the trial ends. In the initial phase of the orienting pretest trial (49s), the experimenter lifts the can or box with both hands, rotates it to show its closed side to the infant, tilts it right and left twice, returns it to the apparatus floor, and then repeats this entire sequence for a total of four times, and leaves by closing the window. For half the infants in each condition, the can will be emptied and the box will be shown closed; for the other infants, the reverse is true. Finally, infants receive the test trials, which are identical to the motion-familiarization trials with the can and box moving on their own across the apparatus floor, and infants watch the paused scene for the final phase of the trial. The primary observer will only be present during the test trials, and so will be naïve to whether the experiment is about animals or self-propelled objects, and to whether it is the first animal or the second animal that has its insides removed.
In the self-propelled/non-agentive condition, the set-up will be exactly the same except that the experimenter remains silent in the sound-familiarization trials, when the box and can are beeping and quacking.

I predict that if infants expect that insides are necessary for animals to move, they will look longer at the animal that has had its insides removed but is still capable of self-propulsion in the test trials, compared to the other animal which did not have its insides removed. If this expectation is related to animal kinds, infants will not have such an expectation in the self-propelled/non-agentive condition, and look equally at the two objects when they move on their own in test, even if one of them no longer possesses any insides.

2.1.1 Method

Participants

Data collection is still ongoing; so far, participants are 8 full-term infants (1 male, range: 6 months, 9 days to 8 months, 18 days, mean = 7 months, 18 days).

Apparatus

The apparatus consists 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 lowers a curtain in front of this opening. Inside the apparatus, the side walls are painted white, and the back wall (made of foam core) and floor are covered with colored adhesive paper. The experimenter is a female native English speaker. She wears a green shirt and sits at a window (34 cm × 48 cm) in the back wall of the apparatus; this back window can be closed with two identical doors. A large screen behind the experimenter hides the testing room. The can (18 cm × 17 cm in diameter) is wrapped with red and gray yarn in alternating stripes; the can has a removable gray felt bottom, and its interior is lined with beige felt. The box (18 cm × 18 cm × 18
cm) is covered with beige adhesive paper and decorated with varying round patches of blue cloth with multicolored dots; the box has a removable beige felt bottom, and its interior is lined with brown felt. In the motion-familiarization trials, a long flat handle is attached to the bottom of the can or box and protrudes through a narrow slit at the bottom of the back wall. In the self-propelled conditions, the experimenter uses the handle to move the can (in a slight bouncing manner) and the box (in a slight zigzag manner) along the apparatus floor, between pre-determined marks. In the sound-familiarization trials, a small speaker is placed behind the can or box; and the wire for the speaker is connected behind the apparatus wall to an MP3 player. The can produces varying synthesized quacking sounds and the box produces varying beeping sounds; these sounds are pre-recorded on the MP3 player and play through the speaker behind the can or box. A small reminder card with the written conversation script is attached to the back of the can or box for the experimenter to follow; in the non-agentive conditions, the can and box produce the same sounds but the experimenter remains silent. In the emptying pretrials, there are two clumps of “insides” placed within the can or box, one pink and one blue. The pink insides are made of a gray oval squeeze toy wrapped with pink rubber ‘tentacles’ and reddish-brown paper tape. The blue insides are made of a gray oval squeeze toy wrapped with powder blue Styrofoam beads and reddish-brown paper tape. The knife is a green plastic lettuce knife. During each test session, one camera captures an image of the events, and another camera captures an image of the infant. The two images are combined, projected onto a television set located behind the apparatus, and monitored by the supervisor to confirm that the trials follow the prescribed scripts. Recorded sessions are also checked off-line for accuracy.

Procedure

Infants sit on a parent’s lap in front of the apparatus; parents are instructed to remain
silent and to close their eyes during the test trials. Two hidden observers help monitor infants’ looking behavior and the primary observers’ responses are used in the analyses. The primary observer leaves the test room for all trials except the test trials in order to be naive during the test trials about infants’ condition and trial order. Inter-observer agreement during the test trials average 91% per trial per infant. Infants are attentive during the initial phases of the two motion-familiarization, sound-familiarization, and emptying/orientation pretrials and looked, on average, for 95%, 95% and 96% of the initial phase of each pair of trials respectively. The final phase of each familiarization trial ends when infants (1) look away for 0.5 consecutive seconds after having looked for at least 0.5 cumulative seconds or (2) look for a maximum of 30 cumulative seconds. Each pretest and test trial ended when infants (1) look away for 2 consecutive second after having looked for at least 2 cumulative seconds or (2) look for a maximum of 600 cumulative seconds.

2.1.2 Results and discussion

Figure 2 presents the mean looking times in the test trials. The results are promising so far; there was a significant difference in infants’ looking times during the final phase of the two motion test trials; \( t(7) = 2.85, p = .025 \); 7/8 infants looked reliably longer during motion trial of the object that has undergone the emptying pretrial \( (M = 9.66, SD = 4.06) \) than object that has undergone the orienting pretrial \( (M = 5.73, SD = 3.46) \) trial. Hence infants detected a violation when the hollowed out can or box is able to move on its own in test. I plan to analyze the data using ANOVA and non-parametric analyses. However, we are still collecting data and observer and manipulation checks will need to be conducted before we can analyze the data.
2.1.3 General discussion

If the results of Experiment 1 are as predicted, it will be important for three reasons. First, it will provide converging evidence that infants distinguish self-propelled agents from objects that are only self-propelled or only agentive; and that infants do not have the same expectations about self-propelled agents and objects which are only self-propelled or only agentive (this is a future condition). Second, the results will indicate that infants expect a novel self-propelled agent not to function after its insides are removed, in accordance with the innards principle. Finally, such results will support the biological hypothesis by demonstrating that infants already possess abstract expectations about the insides of animals.

The next step is to test if infants have different expectations in the self-propelled/non-agentive condition, when the objects are non-agentive. If infants reason that animals, but not non-animals, should not move after their insides have been removed, such results will suggest that infants perceived our can and box as animals (it is a self-propelled agent), believed that the can or box’s insides was removed, and detected a violation when a hollowed out animal was still capable of autonomous motion. If I found similar results in the self-propelled/non-agentive condition, it may be that infants are just interested in objects that have undergone surgery, or that infants expect non-animal self-propelled objects not to be capable of self-initiated motion after their insides are removed, much like a toy with its batteries taken out. The latter explanation is less likely because Setoh et al. (2013) found that infants do not expect insides for objects that are only self-propelled or only agentive. So if such objects had insides, it seems unlikely that infants will expect a loss of function when their insides are removed.

Another interesting control could be to have a condition that is like self-propelled/agentive condition, except that in the test trials, the experimenter moves the can and box on a
tray. If the test effect goes away, it controls for the alternative interpretation that the post-surgery animal is more interesting than the animal that has not undergone surgery.

For a future study, I plan to investigate if infants expect the removal of insides to affect an animal’s agency. I plan to conduct another self-propelled/agentive condition where the set-up is exactly the same as in Experiment 1, except that in test, instead of moving on their own, the test trials will be identical to the sound-familiarization trials – the box and can will respond contingently in conversation with an experimenter. If infants expect that insides are necessary for an animal’s agency, they will look longer at the animal that has had its insides removed but is still capable of having a “conversation” with the experimenter in test, compared to the other animal which did not have its insides removed. If this expectation is related to animal kinds, infants will not have such an expectation in a non-self-propelled/agentive condition (where in the motion-familiarization trials, the box and can will be moved on a tray by an experimenter instead of moving on their own), and they will look equally at the two objects when they have a conversation with the experimenter, even if one of them no longer possesses any insides.

If infants regard an animal’s insides and not an artifact’s insides as essential for its functioning, it supports both the innards principle (Gelman, 1990) and the vitalistic biology view that internal organs and their workings sustain the vitality or life force of animals (Susan Carey, 2000; Gutheil, Vera, & Keil, 1998; G. Hatano & Inagaki, 1994; Inagaki & Hatano, 2004). Such an abstract expectation can lay the foundation for the development of more advanced biological knowledge, such as knowing that different organs have different functions (e.g., the heart pumps blood throughout the blood vessels to circulate blood in our bodies).
CHAPTER 3

DIET

An over-hypothesis is a type of induction with parent predicates (Shipley, 1993). For example, the over-hypothesis ‘kinds of gemstones share the same color’ entails offspring inductive inferences such as ‘emeralds are green’ and ‘rubies are red’. Over-hypotheses allow for the rapid generalization of conceptually relevant properties within kinds, based on small amounts of evidence. For example, upon being told that a blue gem one has never seen before is called a sapphire, one can rely on the over-hypothesis ‘kinds of gemstones share the same color’ to infer that ‘sapphires are blue’.

The biological knowledge that adults and older children possess about animals provides rich over-hypotheses. Consider, in particular, animals’ diets. Most adults and older children would agree that (1) all animals must eat to live and (2) each kind of animal typically eats a narrow range of food found naturally in the habitat it has evolved in. This biological knowledge thus suggests the over-hypothesis, ‘animals of the same kind share the same diet’, and as such makes possible inductive inferences about animal kinds and their diets. If a rabbit is observed to be eating carrots, one can use the over-hypothesis to infer that ‘rabbits eat carrots’ and hence to expect the next rabbit that comes along to eat carrots too. Over-hypotheses allow for the rapid generalization of conceptually relevant properties or behaviors within kinds, based on small amounts of evidence; as such, they contrast with simple generalizations, which may require many exemplars to be extended to an entire kind.

Like adults and older children, preschoolers view diet as kind-relevant for animals (Gelman & Wellman, 1991; Gottfried, Gelman, & Schultz, 1999). Do infants also possess the same expectation? Building on S. Gelman’s approach of studying inductive inferences, we
examine infants’ inductive inferences to understand the nature of their expectations about animal kinds. By studying how infants generalize diet and other properties from one animal to another, we gain insight into what properties (if any) infants expect to be shared by animals of the same kind and by animals of different kinds.

To date, there has been very little research on infants’ ability to reason about dietary preferences. By 13 months, infants are able to attribute a consistent food preference to a computer-animated caterpillar (e.g., for an apple over a slice of cheese; Surian, Caldi, & Sperber, 2007). By 18 months, infants are also able to attribute to a human experimenter a food preference that is different from their own (e.g., for broccoli over goldfish crackers; Repacholi & Gopnik, 1997).

In the present research, we asked whether 14- to 16-month-olds would view a dietary preference (e.g., for cheetos over pretzels) as a property likely to be shared by animals of the same kind. We reasoned that if infants possess an abstract biological framework that includes the over-hypothesis ‘animals of the same kind tend to share the same diet’, then when given evidence that one animal prefers a certain type of food, infants might generalize this dietary preference to another animal of the same kind.

A secondary goal of our research was to explore what properties infants might use to group animals into the same kind. Specifically, after seeing that novel animal-A preferred one food over another, would infants expect novel animal-B to hold the same preference if it was similar to animal-A only in shape and size, similar to animal-A only in texture and color, or dissimilar from animal-A in all of these properties. By using novel, unfamiliar animals and varying the properties of animal-B, we can thus shed light on the properties infants rely on to sort novel animals into distinct kinds. Based on prior research which found that shape indicates
category membership for animal kinds in infants and young children (e.g., Booth & Waxman, 2002; Graham et al., 2004; Graham & Kilbreath, 2007; Markson, Diesendruck, & Bloom, 2008), we expected that, if infants generalized animal-A’s food preference to any other animal, they were most likely to do so for the animal that resembles animal-A in shape and size.

3.1 Experiment 2

Infants were assigned to a one-creature, same-shape, same-texture, or maximally-different condition. In the one-creature condition (adapted from Woodward, 1998), a novel animal consistently demonstrated a preference for one food over another (e.g., preferred Cheetos over pretzels). In the test trials, the locations of the two foods were switched, and the animal went to either the same food as before (same-food trial) or the different food (different-food trial). If, as Surian et al. (2007) found, infants expected the animal to be consistent in its choice of food, then they should expect it to approach the same food in its new location, and they should detect a violation when the animal approached the different food instead.

Infants in the other three conditions saw similar events except that the test trials involved a different animal. Of interest was whether infants would expect this second animal to have the same food preference as the first animal, or whether they would have no expectation about its food preference. The second animal resembled the first only in shape and size (same-shape condition), only in color and texture (same-texture condition), or in none of these properties (maximally-different condition). We expected that infants in the same-shape condition would view the first and second animals as belonging to the same category, but that the infants in the other two conditions would not. On one hand, prior research with infants suggests that shape can indicate category membership for animal kinds (e.g., Booth & Waxman, 2002; Graham et al., 2004; Graham & Kilbreath, 2007; Markson et al., 2008). On the other hand, Booth et al. (2005)
suggested that 18-month-olds were not yet aware that texture could be causally important for animals’ survival (i.e., for camouflage, as protection against the elements, for attracting mates), and Shutts et al. (2009) found that 7-month-olds did not generalize self-motion to toy animals of different shape but the same color.

We reasoned that (1) if infants possessed biological knowledge supporting the over-hypothesis ‘animals of the same kind tend to share the same diet’, and (2) if infants viewed the first and second animals as belonging to the same kind as long as they were similar in shape, but not otherwise, then two predictions followed. First, infants in the same-shape condition should expect the second animal to prefer the same food as the first animal, and they should therefore look reliably longer at the different- than at the same-food test event. Second, infants in the same-texture condition and the maximally-different condition should view the first and second animals as belonging to different kinds, they should hold no expectation about which food the second animal would approach, and they should therefore look about equally at the different- and same-food events.

**Design**

In Experiment 2, 15-month-olds watched live events involving one of four novel creatures (counterbalanced across infants): a gray felt cone topped with chenille, a green fuzzy cone, a gray felt cube topped with chenille, or a green fuzzy cube. Half the infants saw a cone-shaped animal first, and half saw a cube-shaped animal first; half the infants saw a gray animal first, and half saw a green animal first. In the *one-creature* condition (*n* = 18) (Fig. 3), infants received one motion-familiarization trial, three food-familiarization trials, one pretest trial, and two test trials. Each trial had an initial phase and a final phase; looking times during the two phases were computed separately. During the initial phase of the motion-familiarization trial, the
creature moved back and forth across the apparatus on its own (24s); during the final phase, it rested at the center of the apparatus floor. This served to establish that the creature was self-propelled (e.g., Luo et al., 2009). During the initial phase of each food-familiarization trial, while the creature remained stationary at the center of the apparatus, a female experimenter opened a window in the back wall (3s), placed one of the foods on one side of the apparatus floor (4s) and the other food on the other side (4s), and then left, closing the window behind her (4s). Next, the creature moved across the floor towards one of the foods, and stopped in front of it (2s). The creature then “wiggled” in place (5s), as though eating the food. Finally, the creature returned to the center of the apparatus (1s), and paused. Infants could see that the “eaten” food was now gone, only the other food remained. During the final phase of the trial, infants watched this paused scene until the trial ended. The food-familiarization trials served to establish that the creature was agentive; it detected the presence of the foods and acted towards one of them in a goal-directed way. Which food the experimenter introduced first, which side each food was placed, and which food the creature preferred were counterbalanced across infants.

In the pretest trial, there was no creature in the apparatus, and the experimenter switched the locations of where she placed the two foods on the apparatus floor. Finally, all infants received two test trials that were similar to the food-familiarization trials, with the foods in the switched locations. In one trial, the animal ate either the same food as before (same-food event); in the other trial, the animal ate the other food (different-food event). The order of the two events was counter-balanced.

If infants viewed the creature as an animal (it was self-propelled and agentive), understood that the creature ate the food it approached, and attributed a preference for this food to the animal, based on the fact that it consistently chose the same food, then they should expect
the creature to maintain its food preference in test, and they should therefore detect a violation when it approached the other food instead.

Other infants saw events similar to those in the one-creature condition with two exceptions. First, there was an additional trial: after the pretest trial, there was a second motion-familiarization trial where a second animal was introduced; this new animal moved back and forth across the apparatus floor, like the first animal in the first motion-familiarization trial. As mentioned before, the second animal was similar to the first on shape and size (same-shape condition; Fig. 4), in texture and color (same-texture condition; Fig. 5), or in none of these properties (maximally-different condition; Fig. 6). Second, the second animal was also used in the test trials and ate either the same food (same-food event) as the first animal or the other food (different-food event). As explained earlier, we expected that infants in the same-shape condition would look reliably longer at the different- than at the same-food event, but that infants in the same-texture and maximally-different conditions would look about equally at the two events.

3.1.1 Method

Participants

Participants were 70 full-term infants (35 males, range: 14 months, 8 days to 16 months, 7 days, mean = 15 months, 4 days). Another 15 infants were tested but excluded because they looked the maximum time allowed during the familiarization trials (2), were fussy (6), active (2), distracted (1), hungry (1), scared of the animal (1), or because the difference in their looking times in the two test trials was over 2.5 standard deviations from the mean of the condition (2).

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 wore a green shirt and sat at a window (26 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 gray cone (28 cm × 10.5 cm in diameter) and gray box (13 cm × 13 cm in diameter) were wrapped in gray felt and topped with gray chenille, and the green cone (13 cm × 13 cm in diameter) and green cube (28 cm × 10.5 cm in diameter) were wrapped with furry green yarn. A long wooden handle was attached to the bottoms of the cones and cubes and protruded through a narrow slit at the bottom of the back wall. In the motion-familiarization trial, the experimenter used the handle to move the creature along the apparatus floor, between predetermined marks. In the food-familiarization trials, the creature was moved by its handle in front of where the food was placed. Behind the food, in the back wall of the apparatus, was a small trap door. While the creature “ate” the food, a hidden assistant would surreptitiously open the trap door and remove the food, so that it looked as though the creature had eaten it.

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. Before the experiment began, an experimenter
went up to the baby and ate a cheeto and a pretzel from a paper cup, while avoiding eye contact with the baby. This served to show that cheetos and pretzels are foods. Two hidden observers monitored infants’ looking behavior, and the primary observer’s responses were used in the analyses. In all conditions, observers were naive about the order in which the two test events were presented; in conditions with two creatures, observers were also naïve about the identity of second creature.

To assess inter-observer agreement, each trial was divided into 100-ms intervals, and the computer determined in each interval whether the two observers agreed on whether the infant was or was not looking at the event. Percent agreement was calculated for each trial by dividing the number of intervals in which the observers agreed by the total number of intervals in the trial. Inter-observer agreement across the trials averaged 91% per trial per infant. Infants were attentive during the initial phases of all trials and looked, on average, for 95% of each initial phase. The final phase of each 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 30 cumulative seconds.

Preliminary analyses of the test data revealed no interactions of condition and event with infants’ sex, creatures used, or order of the test events; the data were therefore collapsed across these factors in subsequent analyses.

3.1.2 Results and discussion

Infants’ looking times during the test trials (Fig. 7) were analyzed by means of an ANOVA with condition (one-creature, same-shape, same-texture, and maximally-different) as a between-subjects factor and event (same- or different-food) as a within-subject factor. The analysis revealed a significant Condition X Event interaction, $F(1, 66) = 4.82, p = .004$. Planned
comparisons revealed that: infants in the one-creature condition looked reliably at the different-food ($M = 14.53, SD = 7.98$) than at the same-food ($M = 9.81, SD = 6.77$) event, $F(1, 66) = 9.43$, $p = .003$ (14/18 infants showed this pattern); infants in the same-shape condition looked reliably at the different-food ($M = 11.28, SD = 5.75$) than at the same-food ($M = 6.45, SD = 2.84$) event, $F(1, 66) = 9.88, p = .003$ (15/18); infants in the same-texture condition looked about equally at the different-food ($M = 7.91, SD = 5.96$) and same-food ($M = 10.22, SD = 6.53$) events, $F(1, 66) = 2.12, n.s$ (4/17); and infants in the maximally-different condition looked about equally at the different-food ($M = 12.25, SD = 8.52$) and same-food ($M = 11.38, SD = 5.88$) events, $F(1, 66) < 1, n.s$ (9/17).

Thus, infants detected a violation when either the first animal (one-creature condition) or a second animal of the same shape as the first animal (same-shape condition) selected the different food during the test trials. In contrast, infants held no expectations about the food preference of the second animal if it resembled the first animal only in texture and color (same-texture condition) or if it was maximally different from the first animal (maximally-different condition).

These results suggest that infants (1) perceived the various creatures as animals (they behaved as self-propelled agents), (2) believed that the animals ate the offered food (infants exhibited behaviors such as baby-signing “more” or saying “bite” when the animals ate the food during the test session), (3) attributed to the first animal a preference for the food it selected and ate in each familiarization trial, (4) expected the first animal to be consistent in its food preference in the test trials, when the positions of the two foods were switched, and (5) expected the same-shape animal—but not the same-texture animal or the maximally-different animal—to display the same food preference. When the second animal had a different shape than the first,
infants held no expectations about whether it should eat the same food as the first animal or the other food.

Together, these results support the idea that, by 14 to 16 months, infants possess abstract biological knowledge which leads them to view dietary preferences as biologically relevant and supports the over-hypothesis that ‘animals of the same kind tend to share the same diet’: infants expected two animals of the same shape to have the same dietary preference. However, the results are also open to an alternative interpretation: perhaps infants’ responses had no biological basis and were simply driven by a general expectation that like objects tend to have like properties (for example, tend to prefer the same food). This alternative interpretation was addressed in our next experiment.

3.2 Experiment 3

Prior research indicates that infants generally expect similar objects to have similar properties; for example, Baldwin, Markman, and Melartin (1993) found that 9-16-month-olds expected similar, but not dissimilar, objects to possess the same nonobvious property, such as a can wailing or a horn honking. Furthermore, the greater the perceptual similarity between two objects, the more likely infants are to generalize a non-obvious property from one object to the other (Baldwin et al., 1993; Graham et al., 2004; Graham & Kilbreath, 2007; Welder & Graham, 2001). In line with these findings, could the results of Experiment 3 simply reflect infants’ tendency to generalize a non-obvious property – in this case, a food preference— from one animal to a similar animal, but not a dissimilar one?

To examine this alternative interpretation, infants in Experiment 3 were assigned to one-creature and same-shape conditions similar to those in Experiment 2, with one important exception: the first animal now displayed a preference for one toy over another, rather than for
one food over another. Since there is considerable evidence that infants can attribute a toy preference to a non-human agent (e.g., Johnson et al., 2007; Luo & Baillargeon, 2005; Luo, 2011; Shimizu & Johnson, 2004), we predicted that the infants in the one-creature condition would expect the animal to maintain the same toy preference in the test trials and hence would look reliably longer at the different-than at the same-toy event. Of more interest was how infants would respond in the same-shape condition. If infants in the same-shape condition of Experiment 2 generalized the food preference from the first animal to the second animal simply because they assumed that similar objects would share similar non-obvious properties, then infants in the same-shape condition of Experiment 3 should behave in the same way and look reliably longer at the different-toy than at the same-toy event. However, if infants in Experiment 2 responded as they did because they viewed diet as a biological property likely to be shared by animals of the same kind, then infants in Experiment 3 might perform differently: unlike a food preference, a toy preference does not have biological significance for animal kinds, as different individuals can like different toys (e.g., Buresh & Woodward, 2007). In other words, it seems unlikely that infants would hold the over-hypothesis that “animals of the same kind tend to prefer the same toys”. Thus, evidence that infants expected the same-shaped animal to share the same food preference, but not the same toy preference, as the first animal would thus support the conclusion that even infants perceive diet as a biological, kind-relevant property.

Design

15-month-olds were assigned to two conditions. The one-creature condition was identical to that in Experiment 2 except that instead of eating a cheeto or pretzel, the creature chose to play with either rings or blocks. On the toy-familiarization trials and test trials, the experimenter brought in unassembled beads toy (colorful foam beads on a little tray), and unassembled blocks
(three blocks sitting on a little tray). The animal ‘played’ with the toys by assembling them; the ring beads were arranged into a circle, and the blocks were arranged into a stacked pyramid. Newman, Keil, Kuhlmeier, and Wynn (2010) found that 12-month-old infants associated agents with the creation of orderliness. The same-shape condition was also identical to that in Experiment 2 except that, here again, the same-shaped animal chose which toy to play with instead of which food to eat.

3.2.1 Method

Participants

Participants were 32 full-term infants ($n = 36$ when completed; 15 males, range: 14 months, 6 days to 7 months, 7 days, mean = 14 months, 17 days). Another 9 infants were tested but excluded because they looked the maximum time allowed in both tests (2), because they were fussy (1), active (1), scared (1), inattentive (2), or because the difference in their looking times at the two test trials was over 2.5 standard deviations from the mean of the condition (2).

Apparatus

The apparatus was the same as Experiment 2. In the toy-familiarization trials, the creature was moved by its handle in front of where the toy was placed. While the creature “played” the toy, a hidden assistant surreptitiously opened the trap door and switched the unassembled toy with an assembled one, so that it looked as though the creature had assembled it into an orderly pattern.

Procedure

The procedure was the same as Experiment 2 except that the creature played with toys instead of eating food. Infants were attentive during the initial phases of all trials and looked, on average, for 96% of each phase. Inter-observer agreement averaged 93% per trial per infant. As
in Experiment 2, the final phase of each trial ended when the infants (1) looked away for 2 consecutive seconds after having looked for at least 2 cumulative seconds or (2) looked for a maximum of 30 cumulative seconds.

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

3.2.2 Results and discussion

Infants’ looking times during the test trials (Fig. 10) were analyzed by means of an ANOVA with condition (one-creature or same-shape) as a between-subjects factor and event (same- or different-toy) as a within-subject factor. The analysis revealed a significant Condition X Event interaction, $F(1, 30) = 4.33, p = .046$. Planned comparisons revealed that infants in the one-creature condition looked reliably at the different-toy ($M = 12.38, SD = 7.82$) than at the same-toy ($M = 8.05, SD = 6.36$) event, $F(1, 30) = 7.57, p = .010$ (13/17 infants showed this pattern); in contrast, infants in the same-shape condition looked about equally at the different-toy ($M = 12.38, SD = 7.82$) and same-toy ($M = 8.05, SD = 6.36$) events, $F(1, 30) <1, n.s.$ (10/15 infants looked longer at the different-toy event).

Thus, infants (1) identified each creature as an animal (it was self-propelled, detected toys, and acted on the toys in a goal-directed manner); (2) attributed a preference to the first animal for the toy it consistently chose and acted on; (3) expected the first animal to maintain this toy preference in the test trials when the toys’ locations were switched, and (4) did not expect the same-shape animal to have the same toy preference.

I plan to analyze data contrasting the food and toy, same creature and same-shape creature conditions and using ANOVA and non-parametric analyses. However, data collection is
still in progress and observer and manipulation checks will need to be conducted before we can conduct these final data analyses.

In addition, we are conducting an adult survey to understand how adults categorize our creatures. Using the four creature stimuli, adults will be presented with six creature pairs (two pairs with the creatures of the same shape, two pairs with the creatures of the same texture, and two pairs with the maximally different creatures); for each pair, adults will be asked to rate how likely it is that the two creatures are the same kind of animal.

### 3.3 General discussion

The findings of Experiments 2 and 3 suggest four conclusions. First, infants identified our novel self-propelled, agentive creatures as animals. Second, infants in the one-creature condition attributed a food preference (Experiment 2) and a toy preference (Experiment 3) to the first animal, based on its consistent choices in the familiarization trials Third, infants in the same-shape condition expected the same-shape animal to share the food preference of the first animal (Experiment 2), but not its toy preference (Experiment 3). Fourth, infants in the same-texture and maximally-different conditions of Experiment 2 held no expectation about the food preference of the second animal, suggesting that they did not perceive the first and second animals as belonging to the same animal kind.

Together, the results of Experiments 2 and 3 thus support the biological hypothesis, by demonstrating that infants generalized a food preference but not a toy preference across animals of the same kind. These contrasting results suggest that infants did not simply expect similar objects to share similar non-obvious properties. Rather, their expectations were driven in part by a biological framework that views diet, but not toys, as biologically relevant.

These experiments thus provide converging evidence that self-propulsion and agency
(demonstrated by having a food preference) together signal the ontological status of animal, and that infants’ conceptual knowledge in turn guides their reasoning and generalizations about animals’ biologically relevant behaviors.

What are the conceptual origins of infants’ over-hypothesis that animals of the same kind tend to have the same diet? One possibility is that these early expectations are part of the 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 diet preferences arise from cognitive systems that humans evolved to identify predators and prey and, more generally, to deal with animals as a food source (Barrett, 2005; Barrett & Broesch, 2012). Perhaps knowing whether an animal eats plants or other animals is useful information to know if they will be interested in seeking us out as prey.
CHAPTER 4

ANIMAL VOCALIZATIONS

Animals use sounds for hunting, navigating, and communicating. A kind-relevant property for animals is the sounds they make to communicate with members of their own species. Animal vocalizations are facts that maternal generics refer to early on, and are likely to be predicated generically, of the kind as a whole (Gelman, Hollander, Star, & Heyman, 2000). Adults’ and older children’s biological knowledge about animals suggests the over-hypothesis, ‘kinds of animals use similar sounds to communicate’; for example, 4-year-olds expect that a baby cow will moo despite being raised by pigs (Gelman & Wellman, 1991). This over-hypothesis makes it possible for us to draw inferences in absence of specific information, such as ‘all armadillos make the same sound’. Moreover, if we observed that one armadillo made a particular type of sound, say squealing, then we could use the over-hypothesis to infer that ‘armadillos squeal’, and we would expect the next armadillo that comes along to make squealing sounds too (Shipley, 1993).

Do infants also view animal vocalization as a biological, kind relevant property? If infants possess an abstract biological framework, and animal vocalization is a part of it, then when given evidence that one novel animal makes a certain type of sound, they may generalize this property to another animal of the same kind and expect it to sound the same too.

To date, there has been very little work on infants’ expectations about animal vocalizations. Studies of generalization with infants have mostly demonstrated domain-wide inferences, such as animals drink and sleep, cars use keys and transport people, and so on. Nevertheless, Mandler and McDonough (1996) suggested that “it is possible that by 14 months infants would restrict some kinds of properties, such as barking, to dogs, and refuse to generalize
them to other subclasses such as cats” (p. 330). Recent work by Ferry, Hespos, and Waxman (2013) shows that infants do attend to and process animal communications. They found that 3-month-olds who heard human or lemur vocalizations paired with images from one category (e.g., dinosaur) formed an object category and preferred looking at the picture of a new dinosaur as opposed to the picture of a fish during the silent test phase. However, perceptual-tuning happened within 3 months: 6-months-old infants formed an object category when the images were paired with human vocalizations, but not the lemur vocalizations. Hearing backward speech paired with images did not help with category formation at any age.

4.1 Experiment 4

After hearing how a first animal communicates, would infants expect another animal to use similar sounds to communicate? To address this question, we showed infants events involving two animals. First, we demonstrate that a first animal moved on its own and made a particular kind of sound (e.g., it sounded like a whale). Next, we asked whether infants would expect a second animal to have the same vocalizations. We varied whether the second animal was similar to the first animal in shape and size, or whether it differed from the first animal in shape, size, color, and texture. If infants generally (1) view vocalizations as a biological, kind-relevant property and (2) expect animals of the same shape to belong to the same animal kind, then infants should expect same-shape animals to have similar vocalizations.

Design

In Experiment 4, 15-month-olds watched live events involving two of the four novel animals from Experiment 2. Infants were assigned to either a same-shape condition (Fig. 11) or a maximally-different condition (Fig. 12). In the same-shape condition, infants saw two animals from Experiment 2 that shared the same shape and size, but differed in color and texture. In the
maximally-different condition, infants saw two animals from Experiment 2 that were different in shape, size, color, and texture. All infants received a first motion-familiarization trial, a sound-familiarization trial, a second motion-familiarization trial, and two test trials. Each trial had an initial phase and a final phase; looking times during the two phases were computed separately. In the first motion-familiarization trial, the animal moved back and forth across the apparatus floor on its own (24s), and then rested at the center of the apparatus. This served to establish that the animal was self-propelled (e.g., Luo et al., 2009). Half the infants saw a cone-shaped animal first, and half saw a cube-shaped animal first; half the infants saw a gray animal first, and half saw a green animal first. In the sound-familiarization trial, a female experimenter opened a window in the back wall of the apparatus (3s); the creature then initiated a “conversation” by either hooting like an owl (for half the infants in each condition) or making whale calling sounds (for the other infants); the experimenter responded to the animal contingently, in English. The exchange between the animal and experimenter lasted about 50s and served two purposes; it demonstrated that the animal was agentive (Johnson et al., 2007), and it also established the nature of the sounds the animal made to communicate (hooted or sounded like a whale). Finally, the experimenter left, closing the window behind her (2s). During the final phase of the trial, the animal rested at the center of the apparatus, and infants watched this paused scene until the trial ended. In the second motion-familiarization trial, a second animal moved back and forth across the apparatus floor (24s) to establish that it was self-propelled. In the same-shape condition, the second animal resembled the first animal in shape and size but differed in color and texture. In the maximally-different condition, the second animal differed in shape, color, and texture from the first animal.

Finally, all infants received two identical test trials; for half the infants in each condition,
these were same-sound trials; for the other infants, these were different-sound trials. During the initial phase (48 s) of each trial, the first animal stood on the left side of the apparatus and the second animal stood on the right, and they had a “conversation” with each other. The first animal made the same kind of sounds as before, and the second animal made either similar sounds (same-sound trials) or different sounds (different-sound trials). Thus, if the first animal hooted in the sound-familiarization trials, the second animal also hooted too in the same-sound trials, but made whale sounds in the different-sound trials. If the first animal made whale sounds in the sound-familiarization trials, the second animal also made whale sounds in the same-sound trials, or hooted in the different-sound trials. After their “conversation” ended, the two animals paused silently, and the infants watched this paused scene during the final phase of the trial. The primary observer was absent during the motion- and sound-familiarization trials; in addition, the two observers were naïve about the condition infants were assigned to (same-shape or maximally-different).

4.1.1 Method

Participants

Participants were 32 full-term infants (16 males, range: 14 months, 0 days to 16 months, 19 days, mean = 15 months, 3 days). Another 9 infants were tested but excluded because they were fussy (3), active (3), distracted (1), or looked the maximum time allowed during the test trials (2).

Apparatus

The apparatus was the same as in Experiment 2. In the sound-familiarization trial and in the test trials, the animal had a small speaker attached to its back with Velcro; its wire was connected, behind the apparatus wall, to an MP3 player. The recordings were synthesized, pre-
recorded owl sounds or whale sounds, played through the speaker behind the animals. In pilot testing, adults were not able entirely certain what kind of animals produced the sounds, although they could distinguish one sound from the other. More adults guessed ‘a bird’ for the owl hooting sounds, but no one guessed the whale call sounds correctly. It is not crucial to our experiment that the sounds are authentic animal sounds, but it is of greater importance that the two types of sounds are distinct from each other. When the experimenter “conversed” with the animal, a small reminder card with the written conversation script was attached to the back wall of the apparatus, within the same line of sight as the animal, so that the experimenter could look at the animal and say her lines convincingly. When both the animals spoke, they did not say exactly the same thing because the synthesized sound clips were from different segments of owl or whale vocalizations.

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 monitored infants’ looking behavior and the primary observers’ responses were used in the analyses. Inter-observer agreement in the test trials averaged 90% per trial per infant. Infants were attentive during the pretest phase of the test trials and looked, on average, for 72% of each phase. The final phase of each 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 30 cumulative seconds.

Preliminary analyses of the test data revealed no interactions of condition and trial with infants’ sex, objects used or with order of the test trials; the data were therefore collapsed across these factors in subsequent analyses.
4.1.2 Results and discussion

We analyzed infants’ looking times during the initial phases (Fig. 14) of the test trials, when the animals were “conversing”, and during the final phases (Fig. 15) of the test trials, when the animals were silent. Looking times in each phase were averaged across the two trials and analyzed by means of an ANOVA with condition (same-shape or maximally-different) and event (same- or different-sound) as between-subjects factors. The analysis revealed a significant Condition X Event interaction, \( F(1, 28) = 4.24, p = .049 \). Planned comparisons revealed that the infants in the same-shape condition (1) looked reliably longer during the initial phases if the animals made different sounds \( (M = 39.8, SD = 7.03) \) as opposed to similar sounds \( (M = 33.38, SD = 8.43) \), \( F(1, 28) = 13.41, p = .001 \), and similarly (2) looked reliably longer during the initial phases if the animals made different sounds \( (M = 14.91, SD = 7.71) \) as opposed to similar sounds \( (M = 10.21, SD = 5.07) \) \( F(1, 28) = 8.78, p = .006 \). In the maximally-different condition, infants looked about equally at the different-sound and same-sound events in both the initial phases and final phases of the trials, \( F(1, 28) < 1, n.s. \) (initial: different-sound: \( M = 35.33, SD = 13.08 \), same-sound: \( M = 35.11, SD = 9.07 \); final: different-sound: \( M = 9.26, SD = 8.71 \), same-sound: \( M = 10.34, SD = 8.43 \)).

These results suggest that infants 1) identified our novel creatures as animals (each was self-propelled and also agentive, as it responded contingently in conversation with an experimenter or another animal), 2) viewed the first animal’ sound or vocalization as a property likely to be shared with other animals of the same kind, and hence 3) expected the second animal to share the same sound as the first when the two animals were similar in shape (same-shape condition), but not otherwise (maximally-different condition). However, an alternative interpretation was possible for the results, as discussed next.
4.2 Experiment 5

Did the infants in Experiment 4 view vocalization as a biological property and expect animals of the same kind to produce similar vocalization, or were they simply responding based on a general expectation that similar objects tend to have similar non-obvious properties, such as sounding similar (e.g., if this can rattles, this similar can may rattle too)? To rule out this alternative interpretation, we tested infants in two conditions (see Fig. 11 and 13). One was identical to the same-shape condition of Experiment 4, to replicate its results. The other (inert condition) was identical to the first with one exception: in the two motion-familiarization trials, the animals were moved by the experimenter with her right hand through the open back window, and thus they gave no evidence that they were self-propelled. Under these conditions, infants should be less likely to view the creatures as animals, since they were agentive but not self-propelled. If the infants in the same-shape condition of Experiment 4 looked longer at the different- than at the same-sound event because they expected like objects to have like properties, then infants in the inert condition of Experiment 5 should show the same looking pattern, since they saw the same objects. On the other hand, if the infants in the same-shape condition of Experiment 4 looked longer at the different-sound event because they expected animals of the same kind to have the same vocalizations, then infants in the inert condition of Experiment 5 might respond differently: if they no longer viewed the creatures as animals, then they might no longer hold expectations about how they should sound, and they might tend to look equally at different- and same-sound events.
4.2.1 Method

Participants

Participants were 32 full-term infants (16 males, range: 14 months, 3 days to 16 months, 19 days, mean = 15 months, 5 days). Another 17 infants were tested but excluded because they were inattentive (6), fussy (4), afraid of the animal (2), distracted (2), active (1), looked the maximum amount of time in test trials (1), or because the average in their looking times at the two test trials was over 2.5 standard deviations from the mean of the condition (1). Half the infants were assigned to the same-shape condition, the other half were assigned to the inert same-shape condition. Which animal infants saw first, and which sound the animal made was counterbalanced across infants. All infants received two identical test trials; for half the infants in each condition, these were same-sound trials; for the other infants, these were different-sound trials.

Apparatus and Procedure

The apparatus and procedure were the same as in the same-shape condition of Experiment 5, with one exception. Inter-observer agreement across the trials averaged 90% per trial per infant. Infants were attentive during the pretrial phase of test trials and looked, on average, for 76% of each phase.

4.2.2 Results and discussion

Looking times were analyzed as in Experiment 4. We analyzed infants’ looking times during the initial phases (Fig. 14) of the test trials, when the animals were “conversing”, and during the final phases (Fig. 15) of the test trials, when the animals were silent. Looking times in each phase were averaged across the two trials and analyzed by means of an ANOVA with condition (same-shape or inert same-shape) and event (same- or different-sound) as between-
subjects factors. The analysis revealed a significant Condition X Event interaction, $F(1, 28) = 6.13, p = .020$. Planned comparisons revealed that the infants in the same-shape condition looked reliably longer during the initial phases if the animals made different sounds ($M = 38.32, SD = 9.09$) as opposed to similar sounds ($M = 30.86, SD = 8.89$), $F(1, 28) = 19.40, p = .000$, and similarly looked reliably longer during the initial phases if the animals made different sounds ($M = 14.06, SD = 7.33$) as opposed to similar sounds ($M = 7.86, SD = 3.32$), $F(1, 28) = 13.52, p = .001$. In the inert same-shape condition, infants looked about equally at the different-sound and same-sound events in both the initial phases and final phases of the trials, $F(1, 28) < 1.4, n.s.$ (initial: different-sound: $M = 35.70, SD = 9.67$, same-sound: $M = 37.68, SD = 9.92$; final: different-sound: $M = 9.62, SD = 7.78$, same-sound: $M = 11.61, SD = 9.38$).

Thus, infants 1) expected two animals of the same kind (as indicated by the same shape but different texture and color) to sound the same, but 2) did not expect two same-shaped objects that were not animals to sound the same.

### 4.3 General discussion

The findings of Experiments 4 and 5 are important for three reasons. First, infants identified our self-propelled agents as animals. Second, they attributed a distinct vocalization to one animal and generalized the biologically relevant property of vocalization to a second animal of the same kind (where kind is indicated by their common shape). Finally, the results support the biological hypothesis by demonstrating that infants over-hypothesized animal vocalizations across animals of the kind (where kind is indicated by shape similarity), but not objects of the same shape, providing evidence that animal vocalization is biologically relevant when interpreted within a biological framework.
CHAPTER 5

CONCLUSION

The present findings provide evidence that infants possess abstract expectations about animals beyond what is obviously perceptible or deducible from available evidence, which are conceptually driven from a uniquely biological domain. These biological expectations go beyond the physical concept of self-propulsion (internal energy) and the psychological concept of agency (internal states). Instead, infants appear to have a distinct core biological domain, such that they can immediately ascribe to entities identified as animals additional properties that are biological in nature. If Experiment 1 turns out as predicted, it will provide evidence that 8-month-olds make a conceptual distinction between animals versus self-propelled objects, and animals versus agents. There is no cross generalization between the concepts of self-propulsion and agency. If our predictions are supported, it will mean that young infants expect insides to be necessary for function in animals, but do not think that insides are necessary for function in self-propelled objects, or agents, and that they are not using naïve psychology to reason about animals as agents. The results will provide support for the innards principle and for vitalistic biology – insides of an animal are tied to the notion of life, where there is something inside of animals that governs their movement and change.

Experiments 2 to 5 provide converging evidence that infants identify our self-propelled agents as animals, and is innovative in its experimental approach to test infants’ reasoning about animals’ behavior. Instead of asking ‘Do animals eat?’ or ‘Do animals communicate using characteristic vocalizations?’, which is difficult to execute experimentally, we tap on infants’ reasoning about animal kinds as a natural kind category, a powerful kind category that lends itself to over-hypothesis – from one exemplar, infants are able to extend biologically relevant
properties from one category member to another. In Experiment 3, by systematically varying the properties of the second category member, we find that infants generalized biologically relevant properties by shape and not by texture and color, i.e., they categorize animals of the same shape as belonging to the same kind. Hence when there is no other evidence available, infants use shape and not texture and color to infer animal kind membership. Experiment 4 results support the biological hypothesis by demonstrating that infants generalized food but not toy preference across animals of the same kind, providing evidence that infants are reasoning within a biological framework where food is biologically relevant, and toy is not. These experiments provide converging evidence that self-propulsion and agency together signal the ontological status of animal, whereby infants’ conceptual knowledge of animals guides their attention to biologically relevant behaviors which allows them to make over-hypotheses when the behavior is biologically relevant one, as opposed to when it is not.

Experiment 5 provides evidence that infants have the over-hypothesis that ‘Kinds of animals are uniform in sound’; infants expect animals of the same kind (where kind membership is indicated by shape similarity) to share the same vocalizations, and their expectations are violated when the same kind of animal sounds different. There is no expectation of similar vocalizations when the second animal looks very different from the first, and Experiment 5 found that expectations of similar vocalizations is not simply based on a perceptual shape similarity.

Together, these experiments suggest that infants’ 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 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 have biological expectations about objects that were only self-propelled (Experiment 1) or only agentive (Experiment 5). If the results from Experiment 1 hold up, infants expect objects that were both self-propelled and agentive to have physical insides. We predict that only self-propelled objects can still function if their insides are removed; because as Setoh et al. (2013) has found, internal energy or internal states do not at first require physical substrates. 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.
Figure 1. Schematic drawing of the events shown in Setoh et al.’s (2013) 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 Experiment 1 during the test trials as a function of 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 Experiments 2 one-creature condition. Whether the animal preferred the cheeto or the pretzel in familiarization, and whether the animal ate the different food or same food first in test was counterbalanced across infants. Which one of the four novel animals infants saw was also counterbalanced across infants.
Figure 4. Schematic drawing of events shown in Experiment 2 *same-shape* condition. Whether the first animal preferred the cheeto or the pretzel, and whether the second animal ate the different food or same food first in test was counterbalanced across infants. Which two of the four novel animals infants saw was also counterbalanced across infants.
Figure 5. Schematic drawing of events shown in Experiment 2 *same-texture* condition. Whether the first animal preferred the cheeto or the pretzel, and whether the second animal ate the different food or same food first in test was counterbalanced across infants. Which two of the four novel animals infants saw was also counterbalanced across infants.
Figure 6. Schematic drawing of events shown in Experiment 2 *maximally-different* condition. Whether the first animal preferred the cheeto or the pretzel, and whether the second animal ate the different food or same food first in test was counterbalanced across infants. Which two of the four novel animals infants saw was also counterbalanced across infants.
Figure 7. Mean looking times of infants in Experiment 2 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 8. Schematic drawing of the events shown in Experiment 3 toy one-creature condition. Whether the animal preferred the rings or the blocks in familiarization, and whether the animal played with the different toy or same toy first in test was counterbalanced across infants. Which one of the four novel animals infants saw was also counterbalanced across infants.
Whether the animal preferred the rings or the blocks in familiarization, and whether the animal played with the different toy or same toy first in test was counterbalanced across infants. Which one of the four novel animals infants saw was also counterbalanced across infants.
Figure 10. Mean looking times of infants in Experiment 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 11. Schematic drawing of the events shown in Experiment 4 *same-shape animal* condition. Whether the first animal made owl or whale sounds, and infants saw the second animal make the same or different sound in tests was counterbalanced across infants. Which two of the four novel animals infants saw was also counterbalanced across infants.
**Figure 12.** Schematic drawing of the events shown in Experiment 4 *maximally-different animal* condition. Whether the first animal made owl or whale sounds, and infants saw the second animal make the same or different sound in tests was counterbalanced across infants. Which two of the four novel animals infants saw was also counterbalanced across infants.
Figure 13. Schematic drawing of the events shown in Experiment 5 *inert, same-shape* condition. Whether the first animal made owl or whale sounds, and infants saw the second animal make the same or different sound in tests was counterbalanced across infants. Which two of the four novel animals infants saw was also counterbalanced across infants.
Figure 14. Mean looking times of infants in Experiment 4 and 5 during the pretest 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 15. Mean looking times of infants in Experiment 4 and 5 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).
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