

## Developmental Origin of the Animate–Inanimate Distinction

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The authors examine recent theoretical perspectives of the development of the animate–inanimate distinction in infancy. From these theoretical views emerge 7 characteristic properties, each related to physical or psychological causality, that distinguish animates from inanimates. The literature is reviewed for evidence of infants' ability to perceive and understand each of these properties. Infants associate some animate properties with people by 6 months, but they do not associate the appropriate properties to the broad category of animates and inanimates until at least the middle of the 2nd year. The authors offer a theoretical proposal whereby infants acquire knowledge about the properties of different object kinds through a sensitive perceptual system and a domain general associative learning mechanism that extracts correlations among dynamic and static features.

Early research on infants' concept and category development focused primarily on their ability to group objects by form, size, color (e.g., Riciutti, 1965), or functional properties (e.g., Nelson, 1973). In the last 20 years or so, following a shift in research on adult concept formation (e.g., Mervis & Rosch, 1981; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976), a growing number of studies have focused on infants' ability to form categories of objects other than geometric figures. In particular, there has been an emphasis on infants' ability to form categories that adults think of as folk taxonomies, namely, basic-level categories such as cars and dogs and superordinate categories such as animals, vehicles, tools, and plants (see Madole & Oakes, 1999, and Quinn & Eimas, 1996, for reviews). The categories are referred to as *taxonomies* to highlight that the objects within them are the same kind of thing or are "related to one another by means of class inclusion" (Rosch, 1978, p. 27). Studies with preschoolers suggested initially that the basic level might be primary in development (Rosch et al., 1976), but this view has been questioned in the literature (e.g., Mandler, 1992; Mandler, Bauer, & McDonough, 1991).

Recent investigations of the early ability to form taxonomic-like categories have revealed that by 3 months of age infants can form categorical representations of superordinate and basic domains, presumably on the basis of perceptual information alone. Behl-Chadha, Eimas, and Quinn (1995), for example, used the paired-preference paradigm to show that 3-month-olds can form categor-

ical representations of beds, chairs, couches, cabinets, and tables that exclude mammals, and Eimas and Quinn (1994) found that the same age group can form a representation for cats that excludes dogs and female lions. It is generally agreed that infants in these studies know little about these objects as animals, vehicles, dogs, or cats as they are defined by the lexical categories of adults and older children (see Mandler, 1998; Quinn & Eimas, 1996; Rakison, 2000). Few would argue, for instance, that these infants understand in a conceptual sense that furniture and mammals are fundamentally different things or that cats are a distinct ontological class from dogs.

There are, however, those who take a different view when it comes to infants barely 6 months older than those in the studies by Behl-Chadha and colleagues (1995). According to Jean Mandler (1988, 1992, 1998, 2000), infants as young as 7 months may have knowledge (i.e., know the meaning of) objects such as animals and vehicles that goes well beyond information given in the perceptual input. In a series of studies with the sequential touching and object-examining paradigms, Mandler found that infants age 9 months categorize birds as different from planes and animals as different from vehicles (e.g., Mandler & McDonough, 1993, 1998a). Using the generalized imitation technique, Mandler and McDonough (1996, 1998b) found that infants as young as 9 months extend behaviors like drinking and sleeping to novel animals rather than to novel vehicles. Mandler (1992, 2000) claimed that infants' behavior in these cases must be guided by some kind of conceptual understanding about objects. In particular, she proposed that infants' early conceptual categories separate animate entities that are self-starting, move nonlinearly, and cause action at a distance from inanimate objects that are not self-starting, move linearly, and cannot cause action at a distance.

What evidence is there that infants possess the kind of knowledge that Mandler and others (e.g., R. Gelman, Durgin, & Kaufman, 1995; Leslie, 1995) bestow on them? They are certainly not alone in believing that infants are precocious cognizers. There is evidence, for instance, that infants in the 1st year of life have a basic grasp of certain physical principles such as solidity, gravity,

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and causality (e.g., Baillargeon, 1993, 1995, 1999; Spelke, Breilinger, Macomber, & Jacobson, 1992). It nonetheless remains a moot point whether infants have developed an ontological distinction between animate entities—prototypically thought of as people, animals, and insects—and inanimate objects—prototypically thought of as vehicles, plants, rocks, furniture, tools, and toys. Note that vehicles, although one of the most commonly used categories of inanimates in studies on infant classification (e.g., Mandler & Bauer, 1988; Mandler et al., 1991), represent an important but ambiguous example of that domain. That is, vehicles engage in movement probably more than any other inanimate objects, yet the characteristics of this movement could be easily misinterpreted by infants; for example, vehicle movement could appear to infants to be self-propelled or even goal-directed.

To be sure, the origins of the animate–inanimate (A–I) distinction is not a trivial issue, and it has relevance for many disciplines within cognitive science. As Woodward, Sommerville, and Guardo (in press) put it: “One of the most enduring questions in developmental psychology is how children come to understand the distinction between inanimate objects and animate beings” (p. 2). Indeed, the ability to recognize objects as animate or as inanimate is thought to be one of the most fundamental cognitive processes, being one of the final object distinctions made by adults with Alzheimer’s (Hodges, Graham, & Patterson, 1995; Saffron & Schwartz, 1994). For example, adults with semantic dementia lose the distinction between cats and dogs before the distinction between animals and vehicles. It is possible that if this discrimination is one of the last to dissolve, it may be that it is one of the first in place (Mandler & McDonough, 1998a). If knowledge of animates and inanimates provides a crucial building block, if not the building block, for the mind’s representation of objects in the world, it is crucial to determine when and how it develops. Although this issue is clearly an empirical one, the lack of clear definitions within the literature, as well as the relatively recent proposal that such knowledge might develop in the 1st year, means that a comprehensive analysis of this area is lacking but nevertheless greatly needed.

This article is outlined as follows: First, we review the major theoretical proposal on the origins of the A–I distinction. On the basis of this review, we then attempt to provide a new typology of the terms *animate* and *inanimate*. Because of the complexity of these two terms, it is impossible, in our view, to define them in a simple manner. Consequently, our definition of the terms comprises a number of characteristic attributes that conjointly encompass the majority of animates and inanimates. Many of these attributes concern different aspects of motion whereas others concern naïve psychological understanding on the part of the infant. We then assess—by examination of the empirical evidence for early discrimination and understanding of these attributes—the course of development of infants’ A–I distinction. We also attempt to ascertain the role of each characteristic in the development of infants’ understanding of this division. Finally, where current theory within the developmental literature does not account for the findings reviewed in this article, we endeavor, with reference to recent work from our laboratory, to provide a viable thesis that better fits the available data.

### Defining the A–I Distinction: Earlier Accounts and Theoretical Perspectives

In one of the first attempts to delineate the A–I distinction, R. Gelman and Spelke (1981) pointed out that both animate and inanimate objects have physical dimensions such as size, shape, and color, and they are both subject to similar physical transformations (e.g., occlusion, displacement). However, the authors also noted that animate and inanimate objects differ in fundamental ways: (a) animates are agents—they initiate action in a causal event—but inanimates can only be acted on; (b) animate objects grow and reproduce; (c) animates can have mental states such as knowing, perceiving, and emotion; (d) animates possess parts that are directly related to biological function (e.g., limbs permit movement); and (e) only animates are capable of communication and reciprocity.

Although all the attributes listed by R. Gelman and Spelke (1981) to describe the A–I distinction are most likely veridical when describing adult concepts, it is improbable that young children, let alone infants, possess knowledge about some of these attributes. This is particularly true with regard to entities’ biological properties, which are not correctly attributed to animates until the 3rd year or thereafter (Carey, 1985; R. Gelman, 1990; Massey & R. Gelman, 1988; Simons & Keil, 1995). For example, it is not until preschool age that children show an understanding of several aspects of growth, inheritance, and illness (e.g., Backscheider, Shatz, & S. Gelman, 1993; Springer & Keil, 1991). Evidence, from a series of studies by S. A. Gelman and her collaborators (e.g., S. A. Gelman & Coley, 1990; S. A. Gelman & Markman, 1986, 1987) suggests that infants do not use nonobservable biological information to categorize animate objects but that preschoolers do. In these studies, when information was given about the nonobservable properties of objects (e.g., “these things lay eggs”), 2-year-olds tended to categorize on the basis of perceptual appearance, whereas 3- and 4-year-olds tended to categorize on the basis of the given biological information. If infants have developed an A–I distinction, it is therefore unlikely to include nonobservable, biological information.

More recent attempts to delineate the A–I distinction have focused on different aspects of objects’ motion. This focus has an advantage over earlier approaches in that, unlike knowledge about unobservable biological properties, it has at its core information available in the perceptual array. R. Gelman and Spelke (1981) identified one aspect of motion to which infants might be sensitive, that which refers to animates as agents and inanimates as the recipients of action, but their account of how animates and inanimates differ in terms of motion needed further elaboration. Premack (1990) presented a nativist view of the A–I distinction that highlighted the role of object motion, although his principal aim was to provide a theory of intentionality and human social competence. Premack’s theory rests on the basic observation that objects start to move in one of two distinguishable forms—self-instigated motion and caused motion—and that humans of all ages are sensitive to this distinction. An object beginning to move without outside influence typifies self-propelled motion, and caused motion requires that an outside body exert a causal influence to initiate motion. Furthermore, self-propelled objects are expected to engage in goal-directed action that, in turn, is perceived as intentional.

Premack's theory (1990) has as its foundation the motion of objects, but he believed that a higher level of understanding about the A-I distinction comes from the perception of psychological causality, or more specifically, from the perception of intentionality: goals, beliefs, and desires. According to Premack, infants possess an innately specified system that is "triggered" to interpret the action of self-propelled objects as intentional. Thus, irrespective of the perceptual appearance of an object, if it is seen engaging in self-propulsion it is classified as an intentional entity. Similarly, Baron-Cohen (1995) proposed that biological patterns of motion—those associated with people and animals—activate infants' perception of objects as agents with goals and desires. Both Premack's and Baron-Cohen's view are consistent with a number of the mental characteristics of animates described by R. Gelman and Spelke (1981). For example, they argued that only animate things know, perceive, emote, communicate, and reciprocate. It is also generally in accordance with the view that biological understanding in young children derives from a developmentally earlier theory of naïve psychology (e.g., Carey 1985; Inagaki & Hatano, 1987). Moreover, it implies that an examination of the development of the A-I distinction in infancy should include an assessment of early sensitivity to the role that mental states play in the actions of animates.

A similarly nativist, although more explicitly modular view, of infants' causal knowledge underlying the A-I distinction was developed by Leslie (1984, 1988, 1994, 1995). Leslie discussed infants' developing understanding of entities in the world in terms of Agency, but he does not use the term to refer to the entity that causes an event, as is the case for a number of researchers (e.g., R. Gelman & Spelke, 1981; Oakes & Cohen, 1990; see the section *Type of causal role (agent vs. recipient)* for a more detailed definition of Agency). Instead, Leslie (1995) claimed that Agency is not tied to motion but rather to the enduring properties of objects; for example, a person can be the recipient of an action but is nonetheless an Agent. According to Leslie (1984, 1988, 1994, 1995), infants are born with a three-part theory of Agency, each of which activates the other, whereby different brain mechanisms process, in turn, the mechanical, intentional, and cognitive properties of agents. Thus, the perception of spatiotemporal patterns cannot alone lead to an understanding of Agency. Instead, specific modules cause infants to attend to, and to interpret, certain events in certain ways; a hand picking up an object does not in itself suggest asymmetrical mechanical roles, but a "theory of body," biases infants to interpret the hand as having an internal and renewable source of energy or FORCE, and similarly a theory of mind mechanism could help to interpret the action as goal directed or involving intentionality on the part of the agent. Although we save our discussion of the merits of this theory until we have outlined the empirical evidence that Leslie provided in its support, we note our opinion that there are general problems with such a modular approach. It is not clear to us how different modules are somehow "triggered" by the same type of input; for example, it is posited that at one age a hand reaching for a toy triggers a mechanical causality module whereas at a later age the same event might trigger a psychological causality module. Moreover, although we are sympathetic with the idea that distinct brain mechanisms process different kinds of causal information, it is far from obvious why infants need to possess specific mental structures that draw attention to those different sorts of information.

The notion that different types of causality are linked to different types of motion has recently been elaborated on by Mandler (1992, 1998, 2000) in the formation of her more encompassing and influential theory of conceptual development. As discussed earlier, Mandler believed that infants develop a form of conceptual representation—called an *image schema* or *conceptual primitive*—within the 1st year of life, and it is this representational format that guides early categorization and concept formation. In the main, this early form of conceptual representation is best thought of as encapsulating crucial abstract characteristics of objects' spatial structure and movement. According to Mandler (1992, 2000), these image-schemas are constructed through an innate process of *perceptual analysis* in which aspects of the perceptual display are recoded into a simpler, accessible form that embody some kind of meaning (see Karmiloff-Smith, 1992, for a similar view of conceptual development). To give some examples, an image schema that differentiates animals from nonanimals might have at its core self-initiated nonlinear motion, and image schemas that differentiate cows from birds might involve "land-based movement" and "air-based movement."

Mandler argued that the gradual acquisition of image schemas provides infants with knowledge about the "kinds of things" objects are (Mandler & McDonough, 1993), with movement primary in this knowledge. More specifically, she proposed that infants develop three image-schemas for different motion characteristics, which together form the first concept of animacy: (a) the way that objects begin to move, (b) the trajectory that objects follow, and (c) the way objects move with regard to other objects. Animate objects, therefore, can be summarized by image-schemas representing self-motion, animate-motion (moving nonlinearly), and causing action at a distance. In contrast, inanimate objects can be summarized by image schemas representing caused-motion, inanimate-motion (moving linearly), and caused to move through physical contact. Finally, because animate objects tend to be more causally efficacious than inanimate objects, Mandler added a further image schema that represents the notion of agency. This image-schema differs from the one that represents "caused to move through physical contact" only in that two objects are included, with the object acting as an agent moving on a nonlinear, animate path.

At first sight, Mandler's theory (Mandler, 1992, 2000) seems to represent a comprehensive account of the A-I distinction as it might develop in infancy. Mandler's emphasis on object motion as an early basis for the concept of animacy is plausible, particularly given that motion is prime in infant perception almost from birth (e.g., Bertenthal, 1993; Slater, 1989) and that children and adults consider it to be one of the most important criteria for judging unfamiliar entities as animate (e.g., Poulin-Dubois & Héroux, 1994; Richards & Siegler, 1986; Sharp, Candy-Gibbs, Barlow-Elliott, & Petrun, 1985). For example, adults perceive a moving object as inanimate when its motion path is consistent with Newtonian laws of motion and as animate when its motion does not conform to those laws (Stewart, 1984), and adults' perception of point-light displays representing biological or mechanical motion activates distinct areas of the brain (Bonda, Petrides, Ostry, & Evans, 1996). In addition, Mandler's notion of image schemas fits well with the current database on infant cognition, and in particular, with recent research on early imitation and memory (e.g., Mandler & McDonough, 1995; Meltzoff, 1988). The account has

also received support from a number of researchers interested in the emergence of the A–I distinction, most notably R. Gelman (1990; R. Gelman et al., 1995), who expanded her earlier view to provide a more encompassing developmental theory. R. Gelman (1990) proposed that the early ability to distinguish animates from inanimates stems from skeletal causal principles that direct infants to attend and process objects' composition and motion. Although, like Mandler, R. Gelman claimed that motion characteristics are important for the development of an A–I distinction, she claimed that the perception of motion alone is insufficient for such a distinction because in many cases these data are ambiguous (R. Gelman et al., 1995). She thus proposed that infants develop conceptual schemes that deal with the energy sources and materials involved in objects' motion and composition and that these schemes help to direct and interpret information relevant to animates and inanimates.

There are, however, a number of problems with Mandler's theory. First, and like several other researchers, we question Mandler's (e.g., Mandler, 1992, 2000; Mandler et al., 1991; Mandler & McDonough, 1993) rich interpretation of her data. In particular, many have disputed the need to posit that infants have an advanced conceptual understanding in order to explain the data that Mandler presents (e.g., Jones & Smith, 1993; Mueller & Overton, 1998; Quinn, Johnson, Mareschal, Rakison, & Younger, 2000; Rakison, 2000). It has been argued that the results of Mandler and her colleagues' studies on early categorization (e.g., Mandler & Bauer, 1988; Mandler et al., 1991) can be explained by infants' attention to perceptual properties such as object parts, structural configuration, and overall shape (see, e.g., Rakison & Butterworth, 1998a, 1998b; Van de Walle & Hoerger, 1996). Second, Mandler has little in the way of direct evidence that infants younger than 12 months understand that different aspects of motion are related to different kinds of entities. In a number of studies, she has shown that infants are capable of making appropriate inductive inferences about activities such as sleeping and drinking among animate and among inanimate objects, yet no data have been brought forward to demonstrate that infants can make such inductions on the basis of motion. Third, we believe, as does Premack (1990), that motion cues, among other things, lead infants to incorporate some understanding of psychological states into their A–I distinction. Although Mandler has included the notion of agency in her theory, this does not in itself entail a grasp of others as purposive beings (Poulin-Dubois & Shultz, 1988). There is compelling evidence that preschoolers understand that people as well as other animates are intentional entities (e.g., Carey, 1985; Hatano & Inagaki, 1996; Inagaki, 1997), and any comprehensive theory of the A–I distinction in infancy must try to account for this development.

In summary, the theoretical perspectives presented here provide a worthwhile starting point in identifying the nature of the A–I distinction in infancy. In particular, they go some way to delineate the A–I distinction by presenting an analytical perspective of the psychologically, biologically, and physically related attributes of animates and inanimates. Each of the perspectives presented above clearly has merit: R. Gelman and Spelke (1981) presented a description of the attributes on which a developmental account of the A–I distinction could be built; Premack (1990, 1991) highlighted the role of self-propelled motion in the detection of intentionality; Leslie (1995) suggested that infants possess innate modules that interpret the actions of objects as mechanical, intentional,

or cognitive; and Mandler (1992, 1998, 2000) provided a detailed developmental account of the role of motion as the foundation for early representation. Nonetheless, although these different approaches each contain some of the relevant characteristics of the A–I distinction in infancy, we believe that none provides a comprehensive account. Specifically, each theoretical view is lacking in a certain way: R. Gelman and Spelke (1981) provide a taxonomy of animate and inanimate features in which they highlight biological attributes over motion related ones; Premack's (1990) and Leslie's (1995) nativist view leaves little room for a developmental account; and Mandler's (1992) theory remains speculative because of a lack of supporting empirical evidence, and she does not include all aspects of motion and, perhaps crucially, psychological attributes as potential image schemas.

#### Characteristics of the A–I Distinction in Infancy: A New Typology

Because, in our view, there is no definition or theory that fully describes infants' understanding of animates and inanimates, a new approach is needed. The majority of the characteristics covered by each theorist are concerned with physical principles related to the motion of entities in the world, and we agree that these principles are likely to be a crucial part of the foundation for infants' earliest distinction between animates and inanimates. Thus, we propose that the A–I distinction in infancy is rooted in (a) onset of motion (self-propelled vs. caused motion), (b) line of trajectory (smooth vs. irregular), (c) form of causal action (action at a distance vs. action from contact), (d) pattern of interaction (contingent vs. noncontingent), and (e) type of causal role (agent vs. recipient). In addition to these motion-related characteristics, we believe that certain psychological attributes—attributes that are often neglected in accounts of infants' concept of animacy—need to be included. In particular, we posit that additional characteristics of the A–I distinction are (f) purpose of action (goal-directed vs. without aim), and (g) influence of mental states (intentional vs. accidental). We acknowledge the considerable overlap among many of the characteristics listed here. In particular, onset of motion and form of causal action are often confounded, as are the two psychological properties purpose of action and influence of mental states (see, e.g., Bargh, 1990; Meltzoff, 1995; the section *Psychological Causality*). Nonetheless, these seven properties are, in our opinion, the best contenders for the foundation of the A–I distinction in infancy. In contrast to information about biological properties, all can be extracted from information available in the perceptual input—even intentionality and goal-directedness, according to Premack (1990)—and are associated by adults and older children with different types of causal principles (see, e.g., Bassili, 1976; R. Gelman et al., 1995; Heider & Simmel, 1944).

It remains an open question, however, whether there is empirical evidence to support the idea that infants develop an A–I distinction on the basis of these characteristics. That infants can discriminate different kinds of physical and psychological causality—for example, agent from recipient roles—is only a first step in this process. A more stringent test for an understanding of the A–I distinction is whether infants have begun to link one or more aspects of any of the seven characteristic properties with a specific ontological category. In each case, it is important to analyze the extent to which infants' behavior can be interpreted in terms of

*conceptual knowledge*—by which we mean that they have disassociated perceptual information from its source and converted it into some kind of abstract representational format—or in terms of an *association*, by which we mean that they develop expectations about relationships that exist between objects, or their attributes, and a physically or psychologically causal characteristic. More specifically, we use the terms *association* and *associate* throughout this article not to refer to a simple stimulus–response connection (which invariably involves the self), but rather to infants’ detection and representation of perceptually available correlations that exist between spatially or temporally co-occurring objects, properties, or events in the world. A similar interpretation of the term has been recently adopted by a number of researchers who study infants’ attention, across a range of sense modalities, to relations among multiple properties (e.g., Bahrick, 1994; Lewkowicz & Lickliter, 1994; Saffran, Johnson, Aslin, & Newport, 1999; Werker, Cohen, Lloyd, Casasola, & Stager, 1998; Younger & Cohen, 1986). In particular, Werker et al. (1998) interpreted infants’ earliest ability to connect an object with a label as an “associative link” (p. 1290) in the spirit of Oviatt’s (1980, 1982) “recognitory comprehension.” *Recognitory comprehension* is defined as perceptual recognition of a linguistic form, association of that form with an environmental regularity, and an expectation of the correspondence between the linguistic form and the referent. Similarly, in this article we use the term *association* to refer to the ability to connect, for instance, a human hand with reaching or a dog with self-propelled motion.

In the following section, we examine the developmental literature for evidence that a rudimentary A–I distinction develops in infancy and is grounded on the seven characteristics outlined above. Note that, as highlighted above, the overlap among many of the characteristics to be examined means that a test for one is often confounded with a test for another. With this in mind, we endeavor to outline the plausible alternative explanations for the results of the studies that are presented in the following section.

### *Physical Causality*

*Onset of motion (self-propelled vs. caused motion).* An analysis of the literature reveals a relative absence of studies on infants’ ability to discriminate self-propelled from caused motion (but see the section *Form of causal action*). Instead, researchers have tended to focus on infants’ ability to relate different types of onset of motion with different kinds of objects, which, by definition, implies the capacity to discriminate. In one of the first studies on this issue, Golinkoff and Harding (1980, cited in Golinkoff, Harding, Carlson, & Sexton, 1984) used real-life events to test whether 16- and 24-month-old infants find anomalous a chair moving by itself across the room. Results revealed that only the older age group showed some negative emotional response to the anomalous event, from which the authors concluded that by the end of the 2nd year infants understand that inanimate objects are not self-propelled. In contrast, Poulin-Dubois and Shultz (1988) found evidence that this knowledge might be in place approximately 12 months earlier. In one task, they showed 8- and 13-month-old infants novel events in which a female stranger or an inanimate object (ball or chair) moved without any external forces acting on them. The visual fixation time of the 8-month-olds decreased significantly for both events. However, the visual fixation time of the 13-month-olds decreased significantly only for the

event with the stranger. These results, although based largely on visual fixation time, suggest tentatively that by 13 months of age infants know that inanimates are not capable of self-motion.

A more stringent test of infants’ understanding of the origins of objects’ motion came from a study by Poulin-Dubois, Lepage, and Ferland (1996). In one experiment, infants were exposed to an unfamiliar robot, after which they were shown the same robot starting to move without any outside causal force (through a remote-controlled device). Infants were also exposed to a female stranger in the same two conditions. Infants at 9 and 12 months considered the self-propelled robot incongruous, as revealed by an increase in negative affect in comparison to the stationary condition when the robot did not move; yet, there was no such increase in negative affect when the stranger started to move. It should be borne in mind, however, that although the design used by Poulin-Dubois et al. (1996) avoids confounding self-propulsion with action in contact, it is possible that the sheer novelty of a moving robot caused infants’ increase in negative affect. Perhaps infants would respond similarly to any novel object—animate or inanimate—moving without any observable cause.

A further test of infants’ knowledge that the origins of movement differ across ontological categories came from a study with the habituation procedure reported by Spelke, Philips, and Woodward (1995). In the habituation phase, one group of 7-month-old infants saw an object move from the left side of a screen and disappear behind a large central occluder. After a brief delay, a second object that was partially visible on the right side of the occluder began to move in the same direction as the original object and disappear off the right side of screen. In a separate condition, a different group of infants saw the same habituation event but with people in place of the objects. In the test phase, the occluder was removed and infants saw either the two objects or people make contact before the second object or person began to move (caused motion) or the two objects or people make no contact before the second object or person began to move (self-propelled motion). The results revealed that the majority of infants who were habituated to the objects looked longer at the test event with no contact; however, the infants did not show such a preference in the person condition.

These findings provide preliminary evidence that by 7 months infants assume that inanimate objects are not self-propelled—or in other words, that they require contact to start to move—and that people start to move on their own without any direct physical contact. The generalizability of these findings is questionable on two grounds, however. First, the data published in Spelke et al. (1995) reveal only trends or marginally significant effects, which suggests that replication of the study is needed. Second, it is not clear whether infants’ response to animate objects such as cats or dogs would be the same as it is to people. People are not only prototypical animate objects, but they are also the animate objects with which infants have the most exposure (Inagaki & Hatano, 1987; Quinn & Eimas, 1997). Thus, it might be that infants attach certain properties (e.g., self-propulsion) to people before they do so to animate objects in general. This criticism can be levied at the three studies presented here; that is, they might not so much reveal something about infants’ concept of origin of movement as a component of animacy but instead that self-propulsion has become associated with human beings.

*Line of trajectory (smooth vs. irregular).* It is thought that a key characteristic of the A-I distinction is the line of trajectory of an object (e.g., Mandler, 1992; Rakison & Cohen, 1999). This position stems from the fact that, contrary to many of the characteristics discussed here, the type of motion path that an object follows is relatively invariant and often available in the perceptual array. In many cases, for example, infants may see an object moving across their line of vision, but they may not see its origins of motion or see it engender some kind of causal influence on another object. Yet, despite the relative importance and availability of this characteristic of the A-I distinction, an examination of the developmental literature reveals a dearth of studies on the subject.

Impressive evidence that infants are at least sensitive to and recognize biomechanical motion characteristics comes from a series of studies by Bertenthal and his colleagues (e.g., Bertenthal, 1993; Bertenthal, Proffitt, Spetner, & Thomas, 1985). In these studies, young infants were presented with point-light displays specifying a walking motion or some other activity. These displays were created by filming a person in the dark who has lights attached to the head and principal body joints (e.g., elbows, shoulder, hip, wrists). Adults are able to discriminate a wide range of activities (e.g., walking, dancing, and push-ups) when these displays are moving but not when they are static. Displays were also created that represent less coherent movement or random movement. When presented with a coherent, walking point-light display and an incoherent display, infants as young as 3 months prefer to look at the coherent display (Bertenthal et al., 1985). These findings reveal only that infants discriminate random from coherent motion. However, Bertenthal and Davis (1988) found that infants 3 months and older discriminate between an upside-down walker and an upright walker, but only 3-month-olds (and not older infants) discriminate between a display of an upside-down point-light walker and a display of a random pattern of lights. According to the authors, this pattern of results suggests that the 5- and 7-month-old infants recognized the upright display as a human walker and the inverted and random displays as unfamiliar (and thus they were treated equivalently). In contrast, the 3-month-olds differentiated between the upside-down and random displays because they did not recognize that both of them were not a human walker.

Bertenthal (1993) claimed that these studies suggest that by 5 to 6 months of age, infants respond to point-light displays on the basis of their meaning, in addition to their perceptual structure. In other words, infants perceive point-light motion as biomechanical because their prior knowledge affects how they interpret the displays. These data provide compelling evidence that young infants have some level of knowledge about biological motion. Nonetheless, as with the data on onset of motion, they show only that infants attend to aspects of human movement, and the interpretation of the 3-, 5-, and 7-month-olds' responses to the upside-down and random displays is open to question. Furthermore, with the issues at hand in mind, Bertenthal's studies do not help to assess whether infants in the 1st year can discriminate nonbiological (smooth) motion from biological (irregular) motion or whether infants associate one class of objects with smooth motion and another with irregular motion.

Other indirect evidence that infants differentiate animate from inanimate motion—but not smooth from irregular motion—comes from a study by Meltzoff (1994, cited in Slater & Butterworth,

1997), who found that newborns are more likely to imitate tongue protrusion modeled by a real tongue than by a moving tongue-like part attached to an inanimate object. According to Meltzoff and Gopnik (1993), infants behave in this way because they recognize the similarity between the model and themselves, or in other words, they perceive that other people are "like me." Clearly, this is a long way from evidence of infants' sensitivity to different motion paths; however, it suggests that from a very early age infants might attribute certain kinds of movement (in this case, animate tongue protrusion) to people. An interesting test of whether infants generalize the "like me" stance to the category of animates would be to see if they imitate animals such as dogs or cats engaging in tongue protrusion. In any event, in the absence of such data, and given the lack of empirical evidence that infants associate different kinds of movement with different categories of objects, it is difficult to draw strong conclusions about the early understanding of objects' line of trajectory.

*Form of causal action (action at a distance vs. action from contact).* In contrast to the material presented in the previous section on infants' ability to discern different paths of motion, an abundance of research has focused on the ability to perceive, differentiate, and categorize physical causal events. Using a series of simple Michottian (1963) launching events, Oakes and Cohen (1990) habituated 6- and 10-month-olds to direct launch, delay, or noncontact events with toys such as a car, an airplane, and a dinosaur. In the direct launch event, one object moved from left to right across a screen and hit another object that would then move in the same direction until off the screen. In the delay and noncontact events, infants were habituated to a similar sequence, except that there was a short time delay before the second object moved or a gap between the final location of the first object and the starting location of the second object. In the test phase, each set of infants was presented with all three events used during habituation: It was found that 6-month-old infants responded equivalently to all three events but that 10-month-olds treated the direct launch as causal. In other words, 10-month-olds infants habituated to the direct launch event dishabituated to the delay and noncontact events, and infants habituated to one of the noncausal events dishabituated to the direct launch but not to the other noncausal event. This suggests that infants discriminate between action from contact and action at a distance between 6 and 10 months.

These findings have recently been extended in a study by Schlottman and Surian (1999) in which the perception of causation-at-a-distance was examined in 9-month-olds. Infants were habituated to one of two variations of an event in which a red square moved nonrigidly (i.e., like a caterpillar) toward a green square. In neither event was there contact between the two squares; however, in one event the green square moved before the red square had stopped (the reaction event), and in the other event the green square moved a short time after the red square had stopped (the pause event). In the test phase, both groups were shown the same event they had seen during habituation but in reverse. Only the group that was habituated to the reaction event dishabituated to the reversal of the event in the test phase, which suggests that they perceived it in terms of causation-at-a-distance, whereas infants in the pause event did not.

Is there empirical evidence to support the idea that infants associate certain kinds of causality with specific objects? According to Leslie (1982, 1984) by age 7 months infants understand the

role of contact in causal events with animate and inanimate objects. He found that 4- and 7-month-old infants showed surprise when a hand appeared to move a doll without contact (Leslie, 1982). In a later study, he found that 7-month-olds treated as anomalous an event in which a human hand seemed to pick up a doll without contact but did not find anomalous the same event with a wooden block (Leslie, 1984). On the basis of these results, Leslie (1984) argued that within the first 6 or 7 months of life, infants know that spatial contact is crucial in mechanical (i.e., physical) relationships and that human hands act as agents in such mechanical relationships. It is not clear, however, what can be concluded from Leslie's (1984) results, because, as Mandler (1992) has pointed out, infants may have found the sight of a block picking up a doll particularly interesting because such an event is difficult to interpret.

There is also some evidence about infants' knowledge concerning the identity of the recipient of action from contact or from action at a distance. In a study by Legerstee (1994), 4-month-olds played a game of hide and seek during which a person or an object was hidden behind an occluder. Infants tended to search manually, by reaching, when the object was hidden, but they tended to vocalize toward the occluder when the person was hidden. Thus, infants as young as 4 months of age may represent a hidden object as a person or as an inanimate and may know how to cause each of these kinds to act. Further evidence about infants' knowledge in this domain came from a study by Molina, Spelke, and King (1996), who habituated 6-month-old infants to one of two videotaped events in which there were two entities that wore brightly colored hats with a bell at the top. One entity was a person who was fully visible, and a second was behind an occluder that covered all of the entity except the hat. In one event, the talk condition, the person talked to the hidden entity and the hat moved in reply. In the other event, the touch condition, the person spoke to the hidden entity and also reached out and shook it so that the hat moved back and forth. In the test conditions, infants viewed the same events although this time the occluder was removed, revealing either a person or a blue nerf ball. Results revealed that infants looked longer at the person wearing the hat in the touch condition and at the nerf ball in the talk condition. The authors took these behaviors to mean that the 6-month-olds were able to make inference about the identity of an entity on the basis of whether it is caused to act by direct contact or indirect contact. Finally, Poulin-Dubois et al. (1996, Exp. 3) found that 9- and 12-month-olds showed more interest when a robot was caused to move by an experimenter's verbal commands than when a person started moving after being given the same verbal command by the experimenter.

Overall, the data on form of causal action suggest that between ages 4 and 6 months, infants begin to acquire knowledge crucial to the A-I distinction. Namely, animate objects, but not inanimate objects, can act or move without direct physical contact, and animates' functional parts (e.g., hands) are causal only after contact with another object. Together, these studies suggest a complex understanding on the part of the infant about the forms of causal action of which animates and inanimates are capable. Within the 1st year, infants are aware that the cause of human action need not be an external force, and humans can cause action by contact and from a distance by, for instance, picking up an object or making verbal commands (see also the section on *Purpose of action*).

*Pattern of interaction (contingent vs. noncontingent).* Sensitivity to contingency involving the self is one of the most basic human abilities; it is the cornerstone of conditioning. There is a good deal of evidence from face-to-face interaction that infants between 2 and 6 months of age discriminate contingent from noncontingent behavior by their partner (e.g., Murray & Trevarthen, 1985; Nadel, Carchon, Kervella, Marcelli, & Réserbat-Plantey, 1999; cf. Rochat, Neisser, & Marian, 1998). Moreover, there is evidence that infants as young as 3 months respond differentially to people and objects. For example, Field (1979; see also Legerstee, Pomerleau, Malcuit, & Feider, 1987) found that 3-month-old infants look longer at a doll's face than at their mother's face but smile and vocalize more to their mother than to the doll. Similarly, in a more controlled study in which the amount of social contingency of a person and a puppet were equated, Ellsworth, Muir, and Hains (1993) found that 3-month-olds responded with substantially more smiling to the interacting person than to the interacting puppet. This differential behavior toward people and objects may result from infants' ability to recognize the similarity between people and themselves—the "like me" stance—that appears conjointly with the ability for facial and behavioral self-recognition between 3 and 5 months of age (Bahrick, 1995).

We believe, however, that a more advanced form of understanding of contingent and noncontingent behavior may be needed when considering relationships between entities that do not include the self (cf. Mandler, 1992). In many of the studies on early differential responsiveness to people and objects, the infant is an integral part of the socially contingent relationship. To develop knowledge about the contingency of animates and inanimates might require infants to learn from input outside of the richly reciprocal dyadic social context. For infants to determine the patterns of interaction in which a specific entity engages, it is first necessary to identify that entity and then make some kind of induction, from previous experience with same category members, about its motion properties.

According to Watson (1985; Gergely & Watson, 1999), infants possess a perceptual contingency module that provides the foundation for the discrimination of social and nonsocial entities. Watson (1985) claimed that this module helps in the identification of causal contingency magnitudes that are perfect (typically, nonsocial, inanimate entities) and those that are high but less than perfect (i.e., social, animate entities). An example that infants discriminate perfect contingencies from high contingencies, and prefer the latter, came from a study by Magyar and Gergely (1998). Infants between 18 and 36 months were shown two displays, one in which their responses (as given by a computer mouse hidden in a bowl) were replicated perfectly, and one in which their responses were highly but imperfectly reproduced (by an experimenter). Results revealed that infants looked significantly longer at the imitation-based display than at the perfectly contingent display. This study clearly does not provide evidence for a contingency module, but it does show that infants prefer the kind of contingent responses associated with social, animate entities rather than those associated with nonsocial, inanimate entities.

Although there is relatively little evidence that infants understand the relation between levels of contingency and different kinds of entities, it has been shown that infants within the 1st year discriminate between physical events that display contingent or noncontingent action patterns. Rochat, Morgan, and Carpenter

(1997) tested 3- and 6-month-olds' visual preference for two different dynamic events in which two colored discs moved around a screen. In one event, the discs moved independently in a random manner, whereas in the other, the discs' movement was contingent in that one was "chasing" the other (i.e., one disc systematically approached the other disc, which would then move away). Results revealed that of the infants attentive to the displays, the 3-month-olds looked longer at the chasing event and the 6-month-olds looked longer at the noncontingent event. According to the authors, the 6-month-olds may have looked longer at the noncontingent event because, as with adults who were presented with the same displays, they may have been searching for invariants in the seemingly random movements. In any case, the study by Rochat et al. (1997), together with the evidence of causal understanding in the 1st year (e.g., Oakes & Cohen, 1990), suggest that infants discriminate contingent from noncontingent action by age 3 months, and the response caused by the perception of these events differs between 3 and 6 months. More direct evidence for infants' understanding of contingency as it relates to the A-I distinction came from a study by Johnson, Slaughter, and Carey (1998). They tested whether infants would follow the "gaze" of a stuffed animal that either had eyes or did not have eyes and that had behaved contingently or noncontingently. The results revealed that infants followed the orientations of the object when it had previously displayed contingent behavior irrespective of whether it had eyes or not—and when it had behaved noncontingently but possessed eyes. The authors concluded from these results that perhaps it is "an entity's abstract quality of intentionality that drives infants to follow its 'gaze'" (p. 237); that is, they argued that behavioral and morphological characteristics of intentionality caused infants' gaze following rather than attributes of people or animals per se. However, it could also be argued that displays of contingency, and the presence of eyes, helped to capture infants' attention and make it more likely that future behaviors—such as 45° orientations in the Johnson et al. study—were monitored.

In light of these studies, it can be affirmed that infants discriminate, and prefer, highly contingent from noncontingent or perfectly contingent behavior. How does this relate to the A-I distinction? As stated above, there is little evidence that infants associate highly contingent behavior with animates and noncontingent or perfectly contingent behavior with inanimates. It is nonetheless possible that the pattern of interaction among entities, and in particular interaction between the infant and others, acts as a guide in distinguishing social, animate beings from nonsocial, inanimate objects. Perhaps young infants need to observe some kinds of interaction to determine the extent to which an object is social or not. Over time, they might start to associate different levels of contingency with distinct classes of object.

*Type of causal role (agent vs. recipient).* As discussed earlier, an agent in a causal scene is the entity that initiates action, whereas the recipient is the entity that is acted upon. We confine our use of the terms *agent* and *recipient* in this section to the action of an object that is reducible to a mechanical pattern of motion—for example, one object making another object move through contact—as opposed to the action of an entity in pursuit of a goal.

In one of the first attempts to examine infants' understanding of causal events, Leslie (1982, 1988; Leslie & Keeble, 1987) showed Michottian-like events similar to those used by Oakes and Cohen (1990) to test whether 7-month-old infants ascribe agent and

recipient roles to entities in a causal chain. Leslie and Keeble (1987) habituated one group of 7-month-olds to a direct launching event in which one disc-like object moved from left to right across a screen and hit another disc-like object that then moved in the same direction until it moved off the screen. A second group of 7-month-olds was habituated to a similar sequence, except that it involved noncausal launching; that is, there was a short time delay before the second disc moved. In the test phase, each set of infants was presented with the same event to which they were habituated, but it was reversed; for example, the discs moved from the right side of the screen toward the left side of the screen. The logic of this design was that reversing the causal sequence changed both the agent-patient relationship and the spatiotemporal properties. In contrast, reversing the noncausal sequence changed only the spatiotemporal properties. Infants who were habituated to the causal launching event recovered visual attention more than the infants in the noncausal launching event. The authors interpreted the results as meaning that infants inferred agent and recipient roles on the first and second discs in the causal launching event.

These data suggest that before they are 12 months old, infants discriminate the agent from the recipient in a causal scene. Unfortunately, relatively few studies have investigated when infants understand that animates are more likely to act as agents and inanimates are more likely to be recipients of an action. The study by Leslie (1984) described earlier could be interpreted as meaning that infants understand that hands (and therefore possibly people) can act as agents but that blocks of wood cannot (see also Woodward, 1998, 1999, in the section *Purpose of action*). In contrast, in the study by Spelke et al. (1995), 7-month-olds did not regard as anomalous an inanimate object acting as an agent when there was contact between that object and the recipient of the action. This implies that infants may have an advanced form of understanding about agency—after all, inanimates can cause events, such as when a ball knocks over a cup—or that they do not yet associate agency with animates. One of the few studies to test directly infants' knowledge of the causal roles played by animates and inanimates was conducted by Golinkoff and Kerr (1978). They showed events to 15- and 18-month-old infants that contained a role reversal between agents and recipients; that is, the agent of the action alternated between a chair and a man. However, infants responded no differently to the anomalous event that violated the rule of inanimates as agent (when the chair pushed the man) than to the normal event (when the man pushed the chair).

Despite the comparative dearth of empirical studies on this issue, Leslie (1984, 1988, 1994, 1995) has advanced a theoretical account for the development of infants' understanding of *Agency*. As outlined earlier, Leslie believed that infants have three innately derived modules to deal with *Agency*: one for the mechanical properties of objects, one for intentional properties, and one for cognitive properties. Although Leslie's account is very much in line with other modular views of early cognition (e.g., R. Gelman et al., 1995; Spelke et al., 1995), and we are sympathetic to the idea of *Agency* as an enduring property of certain kinds of entities, in our view the proposal suffers from a lack of empirical support. We have already described evidence that 6-month-olds are not sensitive to causality (e.g., Oakes & Cohen, 1990, 1995), and there is considerable evidence that infants do not show any understanding of intentionality until at least 9 to 12 months of age (see the following section on *Psychological Causality*). Presumably, Les-



lie, like other modularitists (e.g., Baron-Cohen, 1995; Premack, 1990), would argue that this evidence is not damning because it takes time for infants' modules to begin to process causal information (i.e., to be "triggered"). Even if this explanation is accepted however, there are other problems with Leslie's modular view. For example, it is unclear to us how independent modules process information that overlap in terms of mechanical and intentional action. Consider, for example, a human hand reaching for a toy: This event contains both mechanical causation (the hand causing the toy to move by contact) and intentional causation (the goals and desires that engendered the reach). How do information-encapsulated modules work together to process such an event, and how might these modules interpret the event differently if all that is involved is mechanical causation (e.g., a claw reaching for toy) or intentional causation (e.g., another person grasps the toy after inferring desire in the original agent to reach the toy)? Finally, it remains far from obvious why it is necessary for specific structures in the brain to draw infants' attention to different kinds of causal information. A perceptual learning mechanism based on correlations of events in the environment—such that perception of part of an event cues an expectation for the other part—could just as easily fulfill the role that Leslie credits to Agency modules. At any rate, it remains an open question in the absence of compelling empirical data about young infants' knowledge of which things in the world are agents or recipients.

### *Psychological Causality*

Thus far we have discussed infants' perception and knowledge of the physical principles underlying the motion of animates and inanimates. As Premack and others (e.g., Leslie, 1994, 1995; Meltzoff, 1995; Premack, 1990) have pointed out, however, no account of the A-I distinction would be complete without covering aspects of psychological causality. The critical test here concerns whether infants understand that only animate beings are capable of intentional and goal-directed acts. We use the term *influence of mental states* to refer to the presence or absence of intentionality behind an action; that is, behavior as the consequence of prior mental states such as desire and belief. We apply the term *purpose of action* to refer to whether or not an action is directed toward the achievement of a goal. It is often the case that the action of animate entities involves both of these characteristics; a cat is thirsty and wants milk (intention) and consequently goes to her bowl to drink (goal). However, it is possible for action to be goal-directed but not intentional, and it is possible to know that an entity acts to achieve a goal but not that mental states—desires, for example—are the driving force to reach that goal (Astington, 1999; Bargh, 1990; Meltzoff, 1995; Zeedyk, 1996). Such a distinction is warranted in order to avoid attribution of intentionality to purely goal-directed systems; for instance, a leaf orients toward sunlight but it has no desire to do so (Bargh, 1990). This position is reiterated by Baron-Cohen (1993), who pointed out that "a goal can be conceptualized as the target of an action or a gaze. An intention, on the other hand, is a mental state that is in principle separable from the action itself" (p. 76). In the same vein, Meltzoff (1995) discussed such a distinction in relation to two types of intentional action: "One involves the nature of the goals that are brought about, that is, the causal consequences on the world; the other involves the relation between the mind and actions" (p. 847). Similarly, infants

might perceive that an entity attempts to reach a goal—a hand reaching for an object—but they might not understand that mental states drive the entity to accomplish that goal.

Consistent with Meltzoff's (1995) and Baron-Cohen's (1995) view, we believe that different psychologically causal phenomena can be viewed as falling under one or other (although in many cases both) of the umbrella terms provided above. Although goal directedness and intentionality are in theory separable kinds of psychological causality, they are often difficult to tease apart empirically, particularly in the case of studies with preverbal infants. For example, preschool children are able to explain and predict human behavior in terms of mental states, such as desires and belief, whereas preverbal infants might react similarly to the action of an animate entity whether or not it is perceived as goal directed or intentional. Nonetheless, recent functional neuroimaging research by Castelli, Happé, Frith, and Frith (2000) with positron emission tomography provided empirical support for this theoretical distinction: They found that different brain regions were activated in adults when they were asked to interpret computer-generated animations that were either mental (e.g., pretending, mocking) or goal directed (chasing). Hence, because it is possible both in principle and in practice to separate "intention-in-the-mind" (influence of mental states) from "intention-in-action" (purpose of action), in the following section we present separate reviews of the available evidence for infants' understanding of each kind of psychological causality.

*Purpose of action (goal directed vs. without aim).* A number of studies already described in this article could be interpreted as showing that infants discriminate goal-directed action from random action. One example is the study by Rochat et al. (1997) in which it was found that infants discriminate two discs moving randomly from two discs moving in an apparent "chase" scenario. Although this interpretation is speculative, it is just as plausible as the conclusion that infants responded differentially to the events because of their distinct levels of contingency. More compelling evidence of infants' perception and understanding of goal-directed action came from an ingenious study by Meltzoff (1995) in which different groups of 18-month-olds saw an actor attempt a simple action; for example, during one action the actor attempted to place a peg in a hole, and in another the actor attempted to put a bead over a hook. One group of infants saw the actor succeed in completing the action, whereas a second group of infants saw the actor attempt the action but not complete it (e.g., missing the hook with the bead). Whether or not they saw a successfully completed action, infants imitated what the actor had intended to do (e.g., they put the bead over the hook). However, when a mechanical device initially modeled the actions, infants did not exhibit the same behaviors. This finding was recently extended by Johnson, Booth, and O'Hearn (1998) who, with the same design developed by Meltzoff (1995), found that 15-month-olds are more likely to imitate an uncompleted action by a monkey doll than by a mechanical device. In conjunction, these studies suggest that 15- to 18-month-olds understand that humans and perhaps animals have goals and that inanimate objects do not; however, it is unclear whether infants interpreted the toy monkey as a toy or as animal. The studies also imply that infants perceive human action as goal directed whether or not the goal of the action is achieved.

Evidence that young infants are sensitive to the goal-directed action of a human actor—represented by a hand and arm—has

recently been reported by Woodward (1998, 1999; Woodward et al., in press). In one series of studies, for example, Woodward (1998) habituated 6- and 9-month-old infants to an event in which a hand and arm moved through a distinctive path to grasp one of two toys. Infants could process these events either by the path of motion (near or far) or by the relation between the hand and the object that was the goal. In the test events, the position of the two toys was reversed and infants saw the actor reach along a different motion path for the same toy as that grasped during the habituation events, or they saw the actor reach along the same motion path as that observed earlier but grasp a different toy. Results revealed that both age groups looked longer at the events that depicted a goal change than at the events that depicted a path change. Crucially, 6-month-olds responded in a different manner when a mechanical claw grasped the toy; that is, they looked longer in the test phase to the path change than to the goal change.

To test whether infants interpret any motion through a rational path toward a goal as an intentional act (see Gergely, Nádasdy, Csibra, & Bíró, 1995, under *Influence of mental states*), Woodward (1999) performed a further series of studies in which 5- and 9-month-olds were habituated either to an actor's arm reach and grasp an object or to an actor's arm reach but land, palm up, on the object. As in Woodward's (1998) earlier study, during the test phase infants saw a change in the path of motion of the arm or a change on the identity of the object that was contacted. Contrary to the prediction of Gergely et al. (1995), 9-month-old infants who were habituated to the event in which the hand grasped the toy looked longer during the test phase at the goal change than the motion path change, whereas infants who were habituated to the event in which the hand came to rest on the toy looked equally at both test events. The younger age group behaved in a similar manner, but the size of the effect was considerably weaker.

In combination, the studies by Woodward (1998, 1999; Woodward & Sommerville, 2000) suggest that around 5 months of age, infants are in the process of learning about the specific abilities of hands and arms in goal-directed actions. By 9 months of age, they associate human hands and arms with goal-directed behaviors, and they are particularly aware that such behaviors are accompanied by specific actions such as smooth, articulated motion and grasping. At 12 months, and possibly earlier (e.g., Munakata, McClelland, Johnson, & Siegler, 1997), infants relate a series of actions to an overarching goal, and they are sensitive to causal relations between the subgoals needed to achieve that overarching goal. Woodward et al. (in press) believed that these studies reveal that infants' perception of intentionality derives not from an innate system sensitive to self-propelled motion, but rather that it is a result of learning and experience. More specifically, they argued (as we do here) that it is likely that the features of an object, not just its motion characteristics, help infants to identify whether it is animate or inanimate, and their everyday experience facilitates the development of an understanding that people are agents who engage in goal-directed activity.

Although we are sympathetic to Woodward's (1998, 1999; Woodward & Sommerville, in press) general view, the data on which it is based require further clarification. As with the study by Leslie (1984), it is difficult to know whether, independent of knowledge about goal directedness, the sight of a rod and claw reaching for an object is difficult for infants to interpret. Furthermore, the evidence described in this section (e.g., Meltzoff, 1995;

Woodward, 1998, 1999), as with much of the research outlined in this article, focuses mainly on infants' knowledge of people and not on their knowledge of animates and inanimates. Although Woodward et al. (in press) highlighted this fact by their conclusion that "infants' notion of agent seems to focus on the person, the type of agent that they most commonly encounter" (p. 19), researchers have thus far not examined infants' notion of goal-directed action as it pertains to animates other than people. In addition, we believe that it might be appropriate to think of the emergence of the attribution of goal-directedness as a form of causal processing that combines aspects of mechanical and psychological causality. As such, it may constitute a period during which infants start to go beyond the spatiotemporal properties of an event, particularly when it involves people, hands, and arms.

*Influence of mental states (intentional vs. accidental action).* As discussed in the previous section, the term *intentional state* refers to the fact that animate entities have internal desires, beliefs, and intentions that give rise to goal-directed behavior. Until recently, it was generally assumed that children did not impute others with intentional states until age 3 or 4 years (e.g., Lewis & Mitchell, 1994; Wellman, 1990). Yet following Leslie's (1987, 1995) proposal that infants have a basic theory of mind mechanism, it has been suggested that during the 2nd year of life children start to attribute mental states such as desire, perception, and emotion to people (e.g., Tomasello, 1995; Wellman, 1993). Evidence to support this claim came from studies on the development of social cognition and in particular from those that examined dyadic and triadic social competencies such as joint visual attention, gaze following, social referencing, and intentional communication (Rochat & Striano, 1999; Tomasello, 1995). It is around 9 months of age, for instance, that infants begin to use deictic gestures (pointing and gazing) to request adult help in obtaining an object (e.g., Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Camaioni, 1992). Such gestures are used not to induce action in an agent by mechanical means but rather by psychological means. Indeed, it has been suggested that the ability to direct attention is the hallmark of intentional behavior (E. J. Gibson & Rader, 1979).

More recently researchers have investigated whether infants impute mental states to objects engaged in events outside of the dyadic or triadic social context. Morgan and Rochat (1997) habituated 3-, 5-, and 7-month-old infants to a chase event similar to that used by Rochat et al. (1997) except that the discs were different colors. In the test phase, infants saw either the same chase event or a role-reversal event in which the colors of the discs were switched. Thus, in the role-reversal event, the chaser became the chasee and the chasee became the chaser, but the spatiotemporal properties remained the same. Results revealed that at 9 months, and to some extent at 7 months, infants dishabituated to the role-reversal event. In other words, the 9-month-olds responded to the events in terms of "who is doing what to whom." The authors claimed that this is evidence of an intentional stance because, unlike the study by Rochat et al. (1997), infants needed to perceive the chase events as social transactions between planning and motivated entities and not just that the two discs were animated and moved differently. One must be careful, however, in attributing an intentional stance to infants on the basis of these data. That there was no physical contact between the two protagonists in the events means that infants' attribution of mental states to the discs

cannot be eliminated; however, a more parsimonious explanation of the data is that infants, as in the study by Leslie and Keeble (1987), interpreted the events in terms of agent and recipient relations.

Perhaps a more compelling demonstration that infants attribute intentionality to goal-directed objects came from a recent series of studies by Gergely, Csibra, and their colleagues (Csibra, Gergely, Bíró, Koós, & Brockbank, 1999; Gergely et al., 1995). Gergely et al. habituated 12-month-old infants to an event in which there was a small disc and a large disc on opposite sides of the screen separated by a rectangular block. Both discs contracted and enlarged and then the small disc moved toward the other disc but stopped at the wall. The small disc returned to its original position and then approached the block, jumped over it, and moved adjacent to the large circle. When adults see this event they tend to interpret it as a baby trying to get to its mother, or in other words, a rational action (surmounting the block) to achieve a goal (gain proximity to the large circle). After babies were habituated to the event, they saw one of two test events in which the block had been removed: In one condition, the small disc repeated the same jumping action as before, and in the other condition, the small disc moved directly toward the large circle without jumping. Gergely et al. (1995) hypothesized that if infants assume that actors take the most rational, optimal path to achieve a goal, then they would recover visual attention more to the familiar, nonrational action than to the new, rational action. The hypothesis was confirmed by the results, from which the authors proposed that by 1 year of age infants apply a teleological stance or a naïve theory of rational action to interpret such events. This interpretative system is thought to take into account the goal state, the action with which this goal is met, and the constraints of the physical world. Hence, an action is perceived as rational as long as it can be explained by reference to a future goal and the action taken to achieve that goal is the most justifiable one available.

Infants' naïve psychological reasoning was examined further in a set of follow-up experiments by Csibra et al. (1999). Using a similar design to that used by Gergely et al. (1995), the authors found in one experiment that infants as young as 9 months of age apply the principle of rational action to interpret action events. Moreover, in additional experiments it was found that 9- and 12-month-olds interpreted the computer-animated figures' actions as rational goal-directed behavior even though several indicators of agency were omitted from the event; that is, self-propulsion, the expanding and contracting movements of the discs, and the smaller disc approaching the larger disc but stopping at the wall. Csibra et al. concluded from these results that perceptual cues of agency or animacy are neither sufficient nor necessary for infants between 9 and 12 months to interpret teleologically the behavior of an entity. The authors admitted that infants most likely learn to associate agency cues with intentional actions; however, they claimed that the initial state of infants' naïve psychological theory allows the interpretation of behaviors as rational and goal directed without reference to the identity of the entity engaging in such behaviors.

The experiments by Gergely et al. (1995) and Csibra et al. (1999) are certainly innovative, yet we wonder how to reconcile the findings of their studies with those that show, for example, that infants younger than 9 months are surprised when a rod or a block exhibits goal-directed behavior (e.g., Leslie, 1984; Woodward, 1998). Moreover, we think it unlikely that infants (or adults for

that matter) overlook the appearance of objects in deciding whether or not they are goal-directed, animate entities (see R. Gelman et al., 1995). Finally, we question the efficacy of an innately specified system that interprets action as rational as long as it follows the most justifiable path to achieve a goal. The study by Woodward (1999) suggests that infants do not interpret all motions through a rational path toward a goal as an intentional act. Moreover, animate entities often follow nonlinear, less justifiable paths to complete a task—for instance, a cat may circle a ball before playing with it—and moving, inanimate entities frequently follow linear, superficially rational paths but are not goal directed (e.g., a ball rolled toward a cat).

Other researchers have investigated early intentional understanding in studies that focus on imitation and referential communication. In one study by Tomasello, Strosberg, and Akhtar (1996), 18-month-old infants were more likely to apply a novel label to an unobservable but desired referent—as indicated by an actor with a smiling face—than to an observable but unwanted referent. Similarly, Baldwin (1991, 1993, 1995) found that 18- to 19-month-olds associate novel labels with the referent of the speaker's focus even if they were focused on a different object when the utterance was made. In such cases, infants avoid incorrect word-label associations by looking for, and following, the speaker's line of gaze. This suggests that infants seek out information that tells them about the referential intentions of a speaker. In a more action-oriented study with the imitation paradigm developed by Meltzoff (1995), Carpenter, Akhtar, and Tomasello (1998) found that 14-month-olds are more likely to repeat an event that is completed by design ("There") than an event completed by accident ("Whoops"). Finally, it has been shown that by 18 months, infants are able to recognize the facial expression appropriate for someone who has a desire for an object fulfilled (Poulin-Dubois, 1999). That is, infants at this age expect people to smile if they obtain a specific object of desire—as shown by gaze and gesture toward that object—and they expect people to be sad if they do not obtain an object of desire. Overall, these studies suggest that in the 2nd year, infants are able to "seek cues in action to aid in deciding whether an explanation in psychological terms is even warranted" (Baldwin & Baird, 1999, p. 218).

To summarize the literature on infants' understanding of psychological causality: Despite recent achievements in documenting the early understanding of people as psychological agents, there is currently no empirical evidence that infants attribute mental states to the broad category of animates. Infants in the 1st year of life may start to identify rational, goal-directed action on the basis of movement alone (Csibra et al., 1999; Gergely et al., 1995), or it may be that they associate goal-directed action only with people (Woodward, 1998, 1999). There is little direct evidence concerning young infants' understanding of people or animals as intentional, purposeful beings. We believe that because infants in the 1st year of life have many opportunities to observe and interact with people, they develop an understanding of people as psychological agents (in particular, as goal-directed entities) earlier than that for other animate entities. We think it likely that during the 2nd year of life, infants become gradually aware of the perceptual similarity between people and animals, and they start to extend their knowledge of people as psychological agents to other animates. This idea is consistent with evidence that suggests that older children use a person analogy rule to attribute biological and

mental properties to animals (Hatano & Inagaki, 1999). However, additional research in which animates are substituted for people is necessary before concrete conclusions can be made, the study by Johnson, Slaughter, and Carey (1998) being a fine illustration of this kind of design.

### *Summary of the Evidence for an Early A-I Distinction*

The main objectives of the preceding sections were (a) to review the extent to which infants discriminate the physically and psychologically causal properties of animates and inanimates and (b) to assess whether infants associate particular objects or categories with those properties; for example, animates are self-propelled whereas inanimates move with an external impetus. We have summarized the findings of the research covered thus far in Table 1. The term *discriminate* is used to refer to evidence that infants distinguish between two instantiations of a particular characteristic, whereas the term *associate* is used to indicate evidence that infants have connected at least one aspect of a characteristic with an animate or inanimate. In many cases, infants can discriminate between the two instantiations of a given characteristic by 6 months of age. Thus, around the middle of the 1st year infants discriminate between causal and noncausal action, contingent and noncontingent motion, agent and patient roles, and perhaps intentional versus accidental movement (see Rochat & Striano, 1999). There is also evidence that infants as young as 3 months recognize that human motion is different from random motion (e.g., Bertenthal & Davis, 1988), although this is not necessarily the same as discriminating between different motion trajectories such as smooth versus irregular paths. It can also be seen that, with the exception of a simple form of goal directedness relating to people (Woodward, 1998, 1999), infants' perception and understanding of A-I characteristics related to psychological causation are not in place until the 2nd year of life.

There is no evidence that infants associate particular motion characteristics with the broader category of animates or inanimates. Indeed, given that infants around 12 months perceive, for example, intentionality or contingency when discs move in a certain manner across a screen (Gergely et al., 1995; Rochat et al.,

1997), it is likely that the first foundations of the components of the A-I distinction are built on general motion characteristics and not the particular motions of animate or inanimate beings. For example, they might expect that "if one object contacts a second object the second object starts to move" rather than "animals are agents and cause other objects to move." As demonstrated by Leslie and Keeble (1987), these events need not be interpreted by referring to the objects involved; that is, infants perceive objects as either agents and recipients whether or not they are animates or inanimates. Likewise, Cohen and Oakes (1993) demonstrated that if information about the identity of the objects involved in a motion event is available, it obscures rather than clarifies the event. This having been said, many of the studies described here revealed that people are associated with animate characteristics very early in life. It is difficult to know whether this predominance of people-related findings is because of constraints on experimental design—that is, no other animates except people are used as stimuli—or whether people act as the prototype for infants' early understanding of certain aspects of animacy (see Legerstee, 2000; Poulin-Dubois, 1999; Quinn & Eimas, 1997). It is quite possible that ample experience with a particular category exemplar allows infants to connect certain elements of motion to that exemplar, and infants' predilection to attend to people at birth, if not shortly thereafter, may facilitate this process (e.g., Meltzoff & Moore, 1977; Morton & Johnson, 1991). Thus, we speculate that infants, having discriminated an animate from an inanimate motion characteristic, probably associate that characteristic first to people.

Perhaps not surprisingly, infants' discrimination of aspects of physical causality appears before their discrimination or understanding of aspects of psychological causality (Poulin-Dubois & Shultz, 1988). We believe that this is because physical causality, relative to psychological causality, is more invariant, it is more readily available in the perceptual array, and it is universal in that it applies both to animates and inanimates. Likewise, and as discussed earlier, an understanding of naïve biology is an even later development because it is acquired through verbal transmission, and perhaps more crucially, it requires the building blocks of knowledge about physical and psychological causality to be in

Table 1  
*Summary of Research on the Animate-Inanimate Distinction in Infancy*

Age (months)	Physical causality				Psychological causality		
	Motion onset	Trajectory	Causal action	Pattern of interaction	Causal role	Purpose of action	Influence of mental states
3-5		Discriminate (Bertenthal, 1993)					
6-8	Associate (Spelke et al., 1995)		Discriminate (Leslie & Keeble, 1987; Cohen & Oakes, 1990)	Discriminate (Rochat et al., 1997)	Associate (Leslie, 1984)	Associate (Woodward, 1998)	Discriminate (Rochat et al., 1997)
9-11	Associate (Poulin-Dubois et al., 1996)		Associate (Poulin-Dubois et al., 1996)				Discriminate (Csibra et al., 1999)
15-17					Associate (Golinkoff & Kerr, 1978)	Associate (Meltzoff, 1995)	

place (Carey, 1995; Inagaki, 1997). That infants do start to recognize people's intentions and goals suggests that the A-I distinction is beginning to develop in earnest toward the middle of the 2nd year, although the studies cited on psychological causality relied only on people as an animate entity.

#### A Perceptual Account for the Development of Infants' A-I Distinction

The preceding sections suggest that the A-I distinction is not an all-or-none phenomenon. Rather, over time infants become able to discriminate, and then associate, certain physical and psychological attributes that adults include in their representation of animates or inanimates. In the 1st year, these properties are very much isolated from each other; for example, an infant might perceive causality and agency but not connect the two. We contend that there is little in the way of evidence that infants have developed a conceptual understanding of (i.e., know the meaning of) animates and inanimates before the middle of the 2nd year. If infants had developed such an understanding in the form of image schemas or otherwise (e.g., R. Gelman, 1990; Mandler, 1992), they should generalize these properties to a wide range of entities. The reviewed literature suggests, however, that this is generally not the case. There is limited evidence from generalized imitation tasks that 14-month-olds correctly extend modeled properties of animals or vehicles to novel category members (e.g., Mandler & McDonough, 1996, 1998b); for example, having seen an experimenter model an animal drinking from a cup, infants are more likely to generalize that behavior to a novel animal than to a novel vehicle. However, infants' ability to make such "appropriate inferences" could be explained by perceptual matching to the target stimulus followed by imitation of the modeled action (see also Quinn et al., 2000). In recent studies in our lab with the generalized imitation technique, for example, we found that 14- and 18-month-olds repeat a motion event—going upstairs, smooth versus irregular motion, and so on—with a novel exemplar from the same domain as that used by the experimenter even if it is drawn from an inappropriate category (Rakison & Poulin-Dubois, 2000a); thus, infants make a cat move up a set of stairs having seen the experimenter model that action with a dog, but they make a truck move up the same set of stairs having seen the experimenter model the action with a car.

We propose that the available data on the A-I distinction can be accounted for by a sensitive perceptual system coupled with a domain general associative learning mechanism that is responsive to correlations in the input. How would such a process operate? There is considerable evidence that infants are sensitive to, and categorize on the basis of, correlations among object features. This is the case not only for relations among static structural features such as legs, heads, and tails (e.g., Younger, 1985, 1993; Younger & Cohen, 1986) but also for relations among aspects of form and dynamic, functional properties (e.g., Madole & Cohen, 1995; Madole, Oakes, & Cohen, 1993). In such cases, the resulting correlations need not be thought of as conceptual, but rather the perception of one component of the correlation triggers an expectation about the presence of the other (see Haith, Wentworth, & Canfield, 1993; Roberts, 1998); that is, the represented associations can be viewed as the initial development of a meaning.

We see no reason why the properties of motion events—specifically, the physically and psychologically causal characteristics of the A-I distinction to which young infants are sensitive—cannot also be acquired in the form of a correlation between two dynamic perceptual cues. Infants experience motion events repeatedly over time, and the invariant perceptual properties of those events are extracted. Often, these invariant properties are salient aspects of motion (e.g., smooth movement, self-propulsion) and conspicuous properties of objects (e.g., large, moving parts). We propose that given the gradual development of knowledge about the A-I distinction suggested by our review of the literature, infants' ability to acquire such correlations undergoes a number of modifications in the 2nd year of life. More specifically, we hypothesize that infants between 7 and 10 months of age become adept at forming associations between static features (e.g., Younger & Cohen, 1986), and they can form associations among simple dynamic cues given repeated exposure to those cues, as in the case of the actions of human hands (Woodward, 1998, 1998; see below) or in the presence of one or more facilitating cues. A facilitating cue is generally naturally occurring and is often a common amodal property that qualifies a relation; for instance, Gogate and Bahrick (1998) found that 7-month-olds relate vowel sounds such as /a/ and /i/ with specific moving objects if the movement of those objects is temporally synchronous with the utterance but not when the objects were stationary or moved asynchronously with the vocalizations.

We propose that it is not until around 14 months of age that infants start to form *elementary* relations between dynamic features; this occurs on-line and requires the presence of both features in their original, dynamic form to cue retrieval of the association. The presence of one part of the correlation would not, at this age, cause the other feature to be activated and recalled. Between 14 and 18 months the represented association become strengthened, presumably through repeated exposure to instances that exhibit the same attribute relationship, such that *secondary* relations develop whereby it is no longer necessary for both dynamic cues to be present to instigate retrieval of the association. In other words, if infants perceive that an object possesses a particular part (be it moving or not at that time), this would cue retrieval of the causal properties associated with that part (Rakison & Poulin-Dubois, 2000b). The claim here is not that primary and secondary relations are qualitatively different; rather, we use the terms to describe the idea that the represented association between two or more attributes allows induction or inference to be made only when it is sufficiently strong. The developmental trend suggested by such associations are very much compatible with Oviatt's (1980, 1982) three components of "recognitory comprehension," which is seen as a form of associative learning that acts as the earliest stage of word acquisition. According to Oviatt (1980, 1982), infants need perceptually to recognize a linguistic form, associate that form with an environmental invariant, and be aware of the match between the linguistic form and the referent. Put in the context of the A-I distinction, the ability to recognize a linguistic form maps onto the discrimination of animate- and inanimate-related characteristics, the ability to associate that linguistic form with an invariant can be seen in terms of an elementary relation, and awareness of the correspondence between the label and the word can be viewed as similar to the development of a secondary relation.

To give more tangible examples of our proposal: Infants may come to expect animate entities to be self-propelled (e.g., Spelke et

al., 1995) because, through repeated observations, they have noticed that cats, dogs, and people, for example, tend to start moving without any external force acting on them and possess legs that move in conjunction with this action. Likewise, infants may find anomalous a wooden block that picks up an object (Leslie, 1984) because the correlation for that motion event invariably includes a human hand. This last example is useful because it highlights the reason that infants initially associate animate properties with people rather than with animate entities in general; that is, people are seen performing animate actions more often than any other animate entities (see also Woodward et al., in press). We speculate that inanimate objects (which tend not to possess moving parts) would not be associated with any particular motion characteristic except, perhaps, that of recipient of action and caused to move by contact.

What evidence is there to support this theory? In a recent series of experiments, we have used the habituation procedure to examine 10-, 14-, and 18-month-old infants' attention to correlations in a motion event scene (Rakison & Poulin-Dubois, 2000b). During the habituation phase of the experiment, infants were presented with two events, each with an object that moved across a screen. Each object had a distinctive set of moving parts, a distinctive body, and a distinctive motion path (rectilinear vs. curvilinear). In the test phase, infants were presented with four events: Three of these test events involved a change in the parts, the body, or the motion of the object, and the other test event was identical to that seen during habituation. Using this kind of Switch design (Werker et al., 1998; Younger & Cohen, 1986), it is possible to examine to which correlations in the event—part-trajectory, body-trajectory, part-body, and part-body-trajectory—infants attended during habituation.

The results of the experiment supported the hypothesis that infants initially associate the trajectory of an object with dynamic, moving parts and then later associate the trajectory with whole objects. Infants at 10 months looked equally long at all four test events, and a later study revealed that infants at this age processed the part and body of the objects independently but that they did not process the different motion paths. Infants at 14 months looked significantly longer at the test event in which the part-trajectory correlation was violated than at the familiar event but not significantly longer at the other test events than at the familiar event. This result is consistent with recent work by Werker et al. (1998), who used the Switch design to show that it is not until 14 months of age that infants form an association between an object and a label, and they do so only when the object in question moves (cf. Gogate & Bahrick, 1998). Finally, infants at 18 months looked longer at all three test events in comparison to the familiar trial, suggesting that they had connected all three attributes. Consistent with the idea that motion has an "attention grabbing" effect on infants (Slater, 1989; Werker et al., 1998) and that younger infants form correlations among dynamic attributes on-line and older infants have expectations about the specific relations among attributes, in a later experiment we found that when the parts did not move 14-month-olds did not form an association among any of the attributes in the event, and 18-month-olds attended to the part-motion relation but not to any of the other attribute correlations available in the event. In a follow-up study, 14-month-olds' sensitivity to the strength of the correlation between two dynamic cues was tested by habituating infants with event in which the parts of

objects moved only for half of the time. Results revealed that infants did not learn the relation between an object's parts and its motion trajectory, suggesting that strong correlations among dynamic attributes (those that are typically causal) are more likely to be learned than moderate correlation among such attributes.

The general pattern of results in these experiments is consistent with the theory proposed here. The experiments suggest how infants may initially distinguish between objects with different movement trajectories by attending to the correlation between dynamic parts and a motion characteristic, a finding that also provides preliminary evidence that certain relations among attributes may be more salient than others (cf. Murphy & Medin, 1985). In addition, the data suggest that at a later age, infants extend this correlation to include whole objects, a conclusion that is in line with the idea that infants process parts before they process wholes (Cohen, 1992; Younger & Cohen, 1986) and with evidence of a shape bias that appears toward the end of the 2nd year (e.g., Baldwin, 1989; Graham & Poulin-Dubois, 1999; Soja, Carey, & Spelke, 1991). Perhaps most important, we believe that infants' behavior in these studies represents evidence of a domain-general associative learning mechanism that is generally responsive to relations among static features in the 1st year of life (e.g., Younger & Cohen, 1986) and becomes increasingly sensitive to relations among dynamic features during the 2nd year of life (e.g., Madole et al., 1993; Werker et al., 1998). This is not to say, however, that infants are unable to detect certain dynamic cues within the 1st year of life; for instance, there is evidence that by 6 months of age infants are sensitive to motion-carried information for depth perception, the segregation of figure from ground, and the perception of object properties (e.g., Arteberry, Craton, & Yonas, 1993; Kellman & Spelke, 1983; Nanez & Yonas, 1994). Rather, we argue that, with the exception of frequently experienced correlations and those in which facilitating cues are present, infants are generally unable to associate dynamic attributes that are causally related until the 2nd year of life.

We acknowledge that there is overlap between our general viewpoint and the notion of perceptual learning developed by E. J. Gibson (E. J. Gibson, 1969; J. J. Gibson & E. J. Gibson, 1955). In particular, we see a parallel between our proposal and mechanisms of attention weighting, feature and stimulus imprinting, differentiation, and unitization (see Goldstone, 1998, for a discussion of these mechanisms). However, although some aspects of our account bear a resemblance to the mechanisms posited by perceptual learning theorists—for example, heightened salience of dynamic cues could be interpreted as attention weighting—we propose a mechanism whereby infants' attention to particular perceptual cues, and the association-based expectations that develop in conjunction with this process, leads to a higher level of cognitive development.

### *Implications*

We see no reason why the same perceptual processing mechanism discussed here cannot also be applied to infants' acquisition of certain physical principles such as solidity, support, or gravity (e.g., Baillargeon, 1993, 1995, 1999; Spelke et al., 1992). That these physical principles are based on relatively invariant associations available in the perceptual input—for instance, an object that is pushed a certain distance over the edge of a supporting

surface falls vertically until it hits another supporting surface—suggests why they might start to be discovered earlier than those related to the A-I distinction. Our proposal may also go some way in explaining the later development of psychological causality as a characteristic that divides animates from inanimates. Psychological causality is considerably more perceptually variable and subtle than physical causality, meaning that extraction of correlations from psychological phenomena is a relatively difficult task. For example, each time an infant observes one entity cause another entity to move, one of those entities can be assigned the role of agent and the other the role of recipient. On the contrary, in the case of goal-directed action it is likely that infants often observe the beginning or the conclusion of a means-end sequence but not the subgoals in between, and they need to infer a psychological cause for any such action in the absence of any physical cause. Moreover, infants' perceptual system is not yet fully developed in the 1st year (Slater, 1997), meaning that otherwise obvious perceptual cues of psychological causality might be overlooked, and even when it is adequately effective, alone it may be insufficient correctly to interpret a physical action as a psychological action. In the type of study designed by Woodward (1998), for instance, infants would be unable to associate goal-directed action with a hand but not a claw if they could not perceptually discriminate those stimuli; and the ability to distinguish the hand from the claw does not necessarily mean that the reaching action of one of them is interpreted as goal directed.

A perceptually based associative learning mechanism can also account for infants' acquisition of the other animate and inanimate motion properties discussed in this article. Indeed, the ability to detect and represent correlations between parts and functional properties may well be the mechanism that allows infants to go beyond the perceptual input and develop what is thought of as conceptual knowledge about objects. For instance, the 18-month-old infants in our correlation studies acted as if they expected parts and motion path to be associated, even when the parts did not move (Rakison & Poulin-Dubois, 2000b). This finding implies that infants may, after repeated exposure to various animals and vehicles, develop knowledge along the lines of "things with legs move on the ground irregularly," "things with wings move in the air irregularly," and "things with wheels move on the ground smoothly." Over time, it is likely that infants incorporate the various motion characteristics of animates and inanimates with the typical physical features possessed by members of these domains; for example, eyes, curvilinear shape, and texture become associated to the motion characteristics of animals and people. These associations would allow infants to make inductions about the properties of novel objects that are not immediately available in the perceptual array, and, perhaps more important, these inductions could be made even if the attribute that is causally related to such properties is not visible; for instance, infants would expect a novel animal to be self-propelled if it has eyes but no legs are discernible. Thus, as argued by Eimas (1994), a perceptually based learning mechanism can, through the continual addition of information through new attribute associations, lead to the development of more meaningful, abstract representations.

Finally, we propose that it is plausible that infants' understanding of aspects of psychologically causal properties of animates and inanimates might develop through the association of object features with particular actions. This development would not neces-

sarily involve associations between an entity and its motion characteristics per se. Instead, we suggest that infants form associations between an entity or the features of that entity (e.g., hands, eyes), the outcome of the action of that entity or its features, and perhaps the effect that the act has on the infant. For instance, the study by Woodward (1998) suggests that 5-month-olds identify goal directedness as related to people—and more specifically, with human hands and arms—but not to inanimates. From our point of view, this would be expected after only a few months of life. After seeing a human hand engage in action many times, particularly during playing, comforting, or feeding, infants come to associate it with an outcome that has some kind of physical and psychological causality. The movement of a hand, particularly a grasping hand (Woodward, 1999), would therefore trigger an expectation that the movement is directed toward a target object or entity and that a physical and perhaps psychological change results.

The association just described would not necessarily take into account the mental state of the entity involved in the goal-directed action; that is, it would not involve an understanding of intentionality. We speculate that the attribution of such mental states to animates also involves an association process but one that initially involves the development of infants' understanding of their own mental states and the connection between those mental states and their own actions. By the middle of the 2nd year, but possibly considerably earlier, infants' flexibility in selecting an action to achieve a goal suggests that they can maintain a mental representation of that goal (see Frye, 1991, for a review). Following repeated experience at attempting such goals, infants start to associate their own mental states with the ability to act. In other words, infants come to understand that they themselves are intentional beings and that their mental states can lead to an action. We suggest that once this connection is made, infants start to attribute similar mental states to entities that share with them some functional attributes—at first, probably hands and arms—and that perform similar goal-directed actions. This idea is consistent with our earlier speculation that infants ascribe psychological states to people before other animate entities; that is, people and infants share a number of body parts and are likely to engage in similar activities, whereas mental state attribution to animals would be based on features that are not instrumental in goal-directed actions (e.g., eyes) and actions that are similar but not identical to those performed by the infant (e.g., eating).

### *Summary*

Over the past 20 years, there has been considerable progress in discovering the extent to which infants comprehend the physical principles (e.g., gravity, solidity) that regulate the motion of objects (e.g., Baillargeon, 1993; Spelke et al., 1992). Similarly, research in social cognitive development has made substantial advances in the study of infants' understanding of people's behavior (see Rochat, 1999). In comparison, relatively little research has focused on the development of infants' understanding of the distinction between animate and inanimate objects; that is, how physical, psychological, and to a lesser degree biological phenomena are integrated into an understanding of the actions and behaviors of different ontological kinds. This article represents one of the first attempts comprehensively to bring together research on the A-I distinction and to connect the first two lines of research

described above. From our review of the literature, we concluded that infants start to discriminate particular animate- from inanimate-related motion characteristics around 6 months of age, most notably those pertaining to motion onset, causal action, pattern of interaction, and causal role. Because of a general absence of converging data for any one of these characteristics and the use of people as animate exemplars in many studies, the evidence for these discriminative abilities is, in the main, not entirely compelling. The available data imply that infants under 12 months have no coherent conceptual A-I distinction, and their performance in many tasks could be explained by responses to perceptual cues. In a similar vein, a number of researchers have recently questioned the rich interpretation of studies that reveal ostensibly a precocious sensitivity to the physical laws that govern the motion of objects (e.g., Bogartz, Shinsky, & Speaker, 1997; Haith & Benson, 1998; Thelen & Smith, 1994).

A central thesis of this article is that infants gradually construct a notion of animacy over the first 2 years of life through a process of continual representational enrichment (see also Eimas, 1994). There is no need, in our opinion, to invoke specialized processes that somehow abstract physical and psychological properties into a separate conceptual system (e.g., Mandler, 1992, 2000). We believe that motion properties, both at the local level in terms of object parts and also at the global level in terms of general movement characteristics, are undoubtedly central to infants' notion of components of the A-I distinction. Moreover, we propose that infants take advantage of the causal relations that exist between dynamic attributes and the physical and psychological actions with which they are causally related by way of a sufficiently sensitive perceptual system, which extracts the pertinent information from motion-related events, and an associative learning mechanism, which connects salient dynamic and static attributes in such events. Thus, infants initially categorize objects on the basis of surface features, after which they begin to associate large, moving parts with the motion characteristics to which they are causally involved. Presumably, these associations are extended between 14 and 18 months of age to include other perceptual features such as, for example, overall shape and smaller less causally relevant attributes. At this point, infants' general notion of animates and inanimates may be considerably more advanced than that of their younger counterparts, and they may become more adept at inferring the physical and psychological causal characteristics of animates and inanimates without the support of the relevant retrieval cue. Such an inference is compatible with evidence that infants between 18 and 24 months start to produce two-word utterances and create pretend play scenarios in which the agent role is fulfilled by an animate and the patient role is fulfilled by an inanimate (e.g., Fenson, 1984).

We agree with R. Gelman et al. (1995) that an A-I distinction, even an immature one, requires more than an understanding of physical causality. In our view, it is an understanding of psychological causality that provides a crucial component toward the development of a competent A-I distinction in infancy. Motion cues can be misleading about whether an entity is animate or inanimate, whereas psychological cues tend not to be. The literature suggests that infants' ability to perceive or understand psychological causality does not develop until 18 months or so (cf. Tomasello, 1995), which implies that although infants may develop expectations about the motion characteristics of objects

toward the end of the 1st year, the meaning of these different characteristics might elude them for another 6 to 8 months. How might future research address the idea that the basis for infants' A-I distinction is first physical causality and then later psychological causality? One potentially fruitful approach might be to pit cues of physical causality and those of psychological causality in the kind of events used by Gergely et al. (1995) and Csibra et al. (1999). It might also prove productive to use the kind of design employed by Johnson et al. (1998) in which infants' behavior toward people, animate-like entities (e.g., puppets), and inanimate objects are compared. Finally, researchers in our laboratory are examining whether infants associate goal directedness and agent-recipient roles to entities on the basis of moving and nonmoving parts.

We hope that the present proposal helps to fill some gaps in the understanding of the development of the A-I distinction in the first 2 years of life. In this article, we have presented two criteria necessary to provide an accurate picture of the development of the A-I distinction in infancy—namely, the ability to discriminate animate from inanimate characteristics and associate those characteristics with particular objects or categories of object—and analyzed the available literature with this in mind. The perceptually oriented learning mechanism for the acquisition of physical and psychological motion characteristics presented here offers a parsimonious and universal account for the development of infants' representations of animates and inanimates. Work in our lab has shown it to have predictive power, at least with regard to the trajectory of objects. The challenge for researchers in this area is to map out when and how other components of the A-I distinction develop and to examine how this knowledge might be connected to other advances in cognition in the 2nd year of life. We believe that this article represents a first step in this direction.

## References

- Arteberry, M. E., Craton, L. G., & Yonas, A. (1993). Infants' sensitivity to motion-carried information for depth and object properties. In C. Granrud (Ed.), *Visual perception and cognition in infancy. Carnegie Mellon symposia on cognition* (pp. 215-234). Hillsdale, NJ: Erlbaum.
- Astington, J. W. (1999). The language of intention: Three ways of doing it. In P. D. Zelazo, J. W. Astington, & D. R. Olsen (Eds.), *Developing theories of intention: Social understanding and self-control* (pp. 295-315). Mahwah, NJ: Erlbaum.
- Backscheider, A. G., Shatz, M., & Gelman, S. (1993). Preschoolers' ability to distinguish living kinds as a function of regrowth. *Child Development, 64*, 1242-1257.
- Bahrck, L. E. (1994). The development of infants' sensitivity to arbitrary intermodal relations. *Ecological Psychology, 6*, 111-123.
- Bahrck, L. E. (1995). Intermodal origins of self-perception. In P. Rochat (Ed.), *The self in infancy: Theory and research* (pp. 349-373). Amsterdam, Netherlands: North-Holland-Elsevier Science.
- Baillargeon, R. (1993). The object concept revisited: New directions in the investigation of infants' physical knowledge. In C. E. Granrud (Ed.), *Visual perception and cognition in infancy* (pp. 265-315). Hillsdale, NJ: Erlbaum.
- Baillargeon, R. (1995). A model of physical reasoning in infancy. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in infancy research* (Vol. 9, pp. 305-371). Norwood, NJ: Ablex.
- Baillargeon, R. (1999). Young infants' expectations about hidden objects: A reply to three challenges. *Developmental Science, 2*, 115-132.
- Baldwin, D. A. (1989). Priorities in children's expectations about object label reference: Form over color. *Child Development, 60*, 1291-1306.



- Baldwin, D. A. (1991). Infants' contribution to the achievement of joint reference. *Child Development*, 62, 875–890.
- Baldwin, D. A. (1993). Early referential understanding: Infants' ability to recognize referential acts for what they are. *Developmental Psychology*, 29, 832–843.
- Baldwin, D. A. (1995). Understanding the link between joint attention and language. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 131–158). Hillsdale, NJ: Erlbaum.
- Baldwin, D. A., & Baird, J. A. (1999). Action analysis: A gateway to intentional inference. In P. Rochat (Ed.), *Early social cognition: Understanding others in the first months of life* (pp. 215–240). Hillsdale, NJ: Erlbaum.
- Bargh, J. A. (1990). Goal intent: Goal-directed thought and behavior are often unintentional. *Psychological Inquiry*, 1, 248–277.
- Baron-Cohen, S. (1993). From attention–goal psychology to belief–desire psychology: The development of a theory of mind and its dysfunction. In S. Baron-Cohen, H. Tager-Flusberg, & D. G. Cohen (Eds.), *Understanding other minds: Perspectives from autism* (pp. 59–83). Oxford, England: Oxford University Press.
- Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and theory of mind*. Cambridge, MA: MIT Press.
- Bassili, J. N. (1976). Temporal and spatial contingencies in the perception of social events. *Journal of Personality and Social Psychology*, 33, 680–685.
- Bates, E., Benigni, L., Bretherton, I., Camaioni, L., & Volterra, V. (1979). *The emergence of symbols: Cognition and communication in infancy*. New York: Academic Press.
- Behl-Chadha, G., Eimas, P. D., & Quinn, P. C. (1995, March). *Perceptually-driven superordinate categorization by young infants*. Paper presented at the meeting of the Society for Research in Child Development, Indianapolis, IN.
- Bertenthal, B. I. (1993). Infants' perception of biochemical motions: Intrinsic image and knowledge-based constraints. In C. Granrud (Ed.), *Visual perception and cognition in infancy: Carnegie-Mellon symposium on cognition* (pp. 175–214). Hillsdale, NJ: Erlbaum.
- Bertenthal, B. I., & Davis, P. (1988, November). *Dynamical pattern analysis predicts recognition and discrimination of biomechanical motions*. Paper presented at the annual meeting of the Psychonomic Society, Chicago, IL.
- Bertenthal, B. I., Profitt, D. R., Spetner, N. B., & Thomas, M. A. (1985). The development of infants' sensitivity to biomechanical motions. *Child Development*, 56, 531–543.
- Bogartz, R. S., Shinskey, J. L., & Speaker, C. J. (1997). Interpreting infant looking: The event set  $\times$  event set design. *Developmental Psychology*, 33, 408–422.
- Bonda, E., Petrides, M., Ostry, D., & Evans, A. (1996). The specific involvement of human parietal systems and the amygdala in the perception of biological motion. *The Journal of Neuroscience*, 16, 3737–3744.
- Camaioni, L. (1992). Mind knowledge in infancy: The emergence of intentional communication. *Early Development and Parenting*, 1, 15–22.
- Carey, S. (1985). *Conceptual change in childhood*. Cambridge, MA: MIT Press.
- Carey, S. (1995). On the origin of causal understanding. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition* (pp. 268–302). Oxford, England: Clarendon.
- Carpenter, M., Akhtar, N., & Tomasello, M. (1998). Fourteen- through 18-month-old infants differentially imitate intentional and accidental actions. *Infant Behavior and Development*, 21, 315–330.
- Castelli, F., Happé, F., Frith, U., & Frith, C. (2000). Movement and mind: A functional imaging study of perception and interpretation of complex intentional movement patterns. *Neuroimage*, 12, 314–325.
- Cohen, L. B. (1992, May). *The myth of differentiation*. Symposium paper presented at the International Conference on Infant Studies, Miami, FL.
- Cohen, L. B., & Oakes, L. M. (1993). How infants perceive a simple causal event. *Developmental Psychology*, 29, 421–433.
- Csibra, G., Gergely, G., Bíró, S., Koós, O., & Brockbank, M. (1999). Goal attribution without agency cues: The perception of "pure reason" in infancy. *Cognition*, 72, 237–267.
- Eimas, P. D. (1994). Categorization in early infancy and the continuity of development. *Cognition*, 50, 83–93.
- Eimas, P. D., & Quinn, P. C. (1994). Studies on the formation of perceptually based basic-level categories in young infants. *Child Development*, 65, 903–917.
- Ellsworth, C. P., Muir, D. W., & Hains, S. M. J. (1993). Social competence and person–object differentiation: An analysis of the still-face effect. *Developmental Psychology*, 29, 63–73.
- Fenson, L. (1984). Developmental trends for action and speech in pretend play. In I. Bretherton (Ed.), *Symbolic play and the development of social understanding* (pp. 249–270). New York: Academic Press.
- Field, T. (1979). Differential behavioral and cardiac responses of 3-month-old infants to a mirror and peer. *Infant Behavior and Development*, 2, 179–184.
- Frye, D. (1991). The origins of intention in infancy. In D. Frye & C. Moore (Eds.), *Children's theories of mind: Mental states and social understanding* (pp. 15–38). Hillsdale, NJ: Erlbaum.
- Gelman, R. (1990). First principles to organize attention to and learning about relevant data: Number and the animate-inanimate distinction as examples. *Cognitive Science*, 14, 79–106.
- Gelman, R., Durgin, F., & Kaufman, L. (1995). Distinguishing between animate and inanimates: Not by motion alone. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition* (pp. 150–184). Oxford, England: Clarendon.
- Gelman, R., & Spelke, E. S. (1981). The development of thoughts about animate and inanimate objects: Implications for research on social cognition. In J. H. Flavell & L. Ross (Eds.), *Social cognition* (pp. 43–66). New York: Academic Press.
- Gelman, S. A., & Coley, J. D. (1990). The importance of knowing a dodo is a bird: Categories and inferences in 2-year-old children. *Developmental Psychology*, 26, 796–804.
- Gelman, S. A., & Markman, E. M. (1986). Categories and induction in young children. *Cognition*, 23, 183–209.
- Gelman, S. A., & Markman, E. M. (1987). Young children's inductions from natural kinds: The role of categories and appearances. *Child Development*, 58, 1532–1541.
- Gergely, G., Nádasdy, Z., Csibra, G., & Bíró, S. (1995). Taking the intentional stance at 12 months of age. *Cognition*, 56, 165–193.
- Gergely, G., & Watson, J. S. (1999). Early socio-emotional development: Contingency perception and the social-biofeedback model. In P. Rochat (Ed.), *Early social cognition: Understanding others in the first months of life* (pp. 101–136). Hillsdale, NJ: Erlbaum.
- Gibson, E. J. (1969). *Principles of perceptual learning and development*. New York: Appleton-Century-Crofts.
- Gibson, E. J., & Rader, N. (1979). Attention: The perceiver as performer. In J. A. Hale & M. Lewis (Eds.), *Attention and cognitive development* (pp. 1–21). New York: Plenum Press.
- Gibson, J. J., & Gibson, E. J. (1955). Perceptual learning: Differentiation or enrichment? *Psychological Review*, 62, 32–41.
- Gogate, L. J., & Bahrick, L. E. (1998). Intersensory redundancy facilitates learning of arbitrary relations between vowel sounds and objects in seven-month-old infants. *Journal of Experimental Child Psychology*, 69, 133–149.
- Goldstone, R. (1998). Perceptual learning. *Annual Review of Psychology*, 49, 585–612.
- Golinkoff, R., Harding, C., Carlson, V., & Sexton, M. E. (1984). The infant's perception of causal events: The distinction between animate and inanimate objects. In L. P. Lipsitt & C. Rovee-Collier (Eds.), *Advances in infancy research* (Vol. 3, pp. 145–151). New York: Ablex.

- Golinkoff, R., & Kerr, J. (1978). Infants' perception of semantically defined action roles in filmed events. *Merrill-Palmer Quarterly*, *24*, 53–61.
- Graham, S. A., & Poulin-Dubois, D. (1999). Infants' reliance on shape to generalise novel labels to animate and inanimate objects. *Journal of Child Language*, *26*, 295–320.
- Haith, M., & Benson, J. B. (1998). Infant cognition. In W. Damon (Series Ed.) & D. Kuhn & R. S. Siegler (Vol. Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (5th ed., pp. 199–254). New York: Wiley.
- Haith, M., Wentworth, N., & Canfield, R. (1993). The formation of expectations in early infancy. In C. Rovee Collier & L. P. Lipsitt (Eds.), *Advances in infancy research* (Vol. 8, pp. 217–249). Norwood, NJ: Ablex.
- Hatano, G., & Inagaki, K. (1996). Cognitive and cultural factors in the acquisition of intuitive biology. In D. R. Olson & N. Torrance (Eds.), *Handbook of education and human development: New models of learning, teaching, and schooling* (pp. 683–708). Cambridge, MA: Blackwell.
- Hatano, G., & Inagaki, K. (1999). Developmental perspective on informal biology. In D. L. Medin & S. Attran (Eds.), *Folkbiology* (pp. 321–354). Cambridge, MA: MIT Press.
- Heider, F., & Simmel, M. (1944). An experimental study of apparent behavior. *American Journal of Psychology*, *57*, 243–259.
- Hodges, J. R., Graham, N., & Patterson, K. (1995). Charting the progression of semantic dementia: Implications for the organisation of semantic memory. *Memory*, *3*, 587–604.
- Inagaki, K. (1997). Emerging distinctions between naïve biology and naïve psychology. In H. M. Wellman & K. Inagaki (Eds.), *The emergence of core domains of thought: Children's reasoning about physical, psychological, and biological phenomena* (pp. 27–44). San Francisco: Jossey-Bass.
- Inagaki, K., & Hatano, G. (1987). Young children's spontaneous personification as analogy. *Child Development*, *58*, 1013–1020.
- Johnson, S., Booth, A., & O'Hearn, K. (1998, April). *Inferring the goals of a non-human agent*. Poster session presented at the International Conference on Infant Studies, Atlanta, GA.
- Johnson, S., Slaughter, V., & Carey, S. (1998). Whose gaze will infants follow? The elicitation of gaze-following in 12-month-olds. *Developmental Science*, *1*, 233–238.
- Jones, S. S., & Smith, L. B. (1993). The place of perception in children's concepts. *Cognitive Development*, *8*, 113–139.
- Karmiloff-Smith, A. (1992). *Beyond modularity*. Cambridge, MA: MIT Press.
- Kellman, P. J., & Spelke, E. S. (1983). Perception of partly occluded objects in infancy. *Cognitive Psychology*, *15*, 483–524.
- Legerstee, M. (1994). Patterns of 4-month-old infant responses to hidden silent and sounding people and objects. *Early Development and Parenting*, *3*, 71–80.
- Legerstee, M. (2000). Domain specificity and the epistemic triangle: The development of the concept of animism in infancy. In F. Lacera, C. Von Hofsten, & M. Heimann (Eds.), *Transitions in perception, cognition, and action* (pp. 193–212). Mahwah, NJ: Erlbaum.
- Legerstee, M., Pomerleau, A., Malcuit, G., & Feider, H. (1987). The development of infants' responses to people and a doll: Implications for research in communication. *Infant Behavior and Development*, *10*, 81–95.
- Leslie, A. M. (1982). The perception of causality in infants. *Perception*, *11*, 173–186.
- Leslie, A. M. (1984). Infant perception of a manual pick-up event. *British Journal of Developmental Psychology*, *2*, 19–32.
- Leslie, A. M. (1987). Pretence and representation: The origins of "theory of mind." *Psychological Review*, *94*, 412–426.
- Leslie, A. M. (1988). The necessity of illusion: Perception and thought in infancy. In L. Weiskrantz (Ed.), *Thought without language* (pp. 185–210). Oxford, England: Clarendon.
- Leslie, A. M. (1994). ToMM, ToBy, and agency: Core architecture and domain specificity. In L. Hirschfeld & S. Gelman (Eds.), *Mapping the mind: Domain specificity in cognition and culture* (pp. 119–148). New York: Cambridge University Press.
- Leslie, A. M. (1995). A theory of agency. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition* (pp. 121–141). Oxford, England: Clarendon.
- Leslie, A. M., & Keeble, S. (1987). Do six-month-old infants perceive causality? *Cognition*, *25*, 265–288.
- Lewis, C., & Mitchell, P. (Eds.). (1994). *Children's early understanding of mind: Origins and development*. Hove, England: Erlbaum.
- Lewkowicz, D. J., & Lickliter, R. (Eds.). (1994). *Development of intersensory perception: Comparative perspectives*. Hillsdale, NJ: Erlbaum.
- Madole, K. L., & Cohen, L. B. (1995). The role of object parts in infants' attention to form–function correlations. *Developmental Psychology*, *31*, 637–648.
- Madole, K. L., & Oakes, L. M. (1999). Making sense of infant categorization: Stable processes and changing representations. *Developmental Review*, *19*, 263–296.
- Madole, K. L., Oakes, L. M., & Cohen, L. B. (1993). Developmental changes in infants' attention to function and form–function correlations. *Cognitive Development*, *8*, 189–209.
- Magyar, J., & Gergely, G. (1998, April). *The obscure object of desire: "Nearly, but clearly not like me." Perception of self-generated contingencies in normal infants and children with autism*. Poster session presented at the International Conference on Infant Studies, Atlanta, GA.
- Mandler, J. M. (1988). How to build a baby: On the development of an accessible representational system. *Cognitive Development*, *3*, 113–136.
- Mandler, J. M. (1992). How to build a baby: II. Conceptual primitives. *Psychological Review*, *99*, 587–604.
- Mandler, J. M. (1998). Representation. In W. Damon (Series Ed.) & D. Kuhn & R. S. Siegler (Vol. Eds.), *Handbook of child psychology: Vol. 2. Cognition, perception, and language* (5th ed., pp. 255–308). New York: Wiley.
- Mandler, J. M. (2000). Perceptual and conceptual processes in infancy. *Journal of Cognition and Development*, *1*, 3–36.
- Mandler, J. M., & Bauer, P. J. (1988). The cradle of categorization: Is the basic level basic? *Cognitive Development*, *3*, 247–264.
- Mandler, J. M., Bauer, P. J., & McDonough, L. (1991). Separating the sheep from the goats: Differentiating global categories. *Cognitive Psychology*, *23*, 263–298.
- Mandler, J. M., & McDonough, L. (1993). Concept formation in infancy. *Cognitive Development*, *8*, 291–318.
- Mandler, J. M., & McDonough, L. (1995). Long-term recall of event sequences in infancy. *Journal of Experimental Child Psychology*, *59*, 457–474.
- Mandler, J. M., & McDonough, L. (1996). Drinking and driving don't mix: Inductive generalization in infancy. *Cognition*, *59*, 307–335.
- Mandler, J. M., & McDonough, L. (1998a). On developing a knowledge base in infancy. *Developmental Psychology*, *34*, 1274–1288.
- Mandler, J. M., & McDonough, L. (1998b). Studies in inductive inference in infancy. *Cognitive Psychology*, *37*, 60–96.
- Massey, C. M., & Gelman, R. (1988). Preschoolers' ability to decide whether a photographed unfamiliar object can move itself. *Developmental Psychology*, *24*, 307–317.
- Meltzoff, A. N. (1988). Infant imitation and memory. Nine-month-olds in immediate and deferred tests. *Child Development*, *59*, 217–225.
- Meltzoff, A. N. (1995). Understanding the intentions of others: Re-enactment of intended acts by 18-month-old children. *Developmental Psychology*, *31*, 838–850.
- Meltzoff, A. N., & Gopnik, A. (1993). The role of imitation in understanding persons and developing a theory of mind. In S. Baron-Cohen, H.

- Tager-Flusberg, & D. Cohen (Eds.), *Understanding other minds: Perspectives from autism* (pp. 335–365). Oxford, England: Oxford University Press.
- Meltzoff, A. N., & Moore, M. K. (1977). Imitation of facial and manual gestures by human neonates. *Science*, *198*, 75–78.
- Mervis, C. B., & Rosch, E. (1981). Categorization of natural objects. *Annual Review of Psychology*, *32*, 89–115.
- Michotte, A. (1963). *The perception of causality*. London: Methuen.
- Molina, M., Spelke, E. S., & King, D. (1996, April). *The animate-inanimate distinction in infancy: Sensitivity to distinctions between social interactions and object manipulations*. Poster session presented at the International Conference on Infant Studies, Providence, RI.
- Morgan, R., & Rochat, P. (1997, April). *The perception of social causality in 3- to 9-month-old infants*. Poster presented at the Conference on Developmental Processes in Early Social Understanding, University of Michigan, Ann Arbor.
- Morton, J., & Johnson, M. H. (1991). CONSPEC and CONLERN: A two-process theory of infant recognition. *Psychological Review*, *98*, 164–181.
- Mueller, U., & Overton, W. F. (1998). How to grow a baby: A re-evaluation of image-schema and Piagetian action approaches to representation. *Human Development*, *41*, 71–111.
- Munakata, Y., McClelland, J. L., Johnson, M. H., & Siegler, R. (1997). Rethinking infant knowledge: Toward an adaptive process account of successes and failures in object-permanence tasks. *Psychological Review*, *104*, 686–713.
- Murphy, G. L., & Medin, D. L. (1985). The role of theories in conceptual coherence. *Psychological Review*, *92*, 289–316.
- Murray, L., & Trevarthen, C. (1985). Emotional regulation of interactions between two-month-olds and their mothers. In T. M. Field & N. A. Fox (Eds.), *Social perception in infants* (pp. 177–197). Norwood, NJ: Ablex.
- Nadel, J., Carchon, I., Kervella, C., Marcelli, D., & Réserbat-Plantey, D. (1999). Expectancies for social contingency in 2-month-olds. *Developmental Science*, *2*, 164–173.
- Nanez, J. E., & Yonas, A. (1994). Effects of luminance and texture motion on infant defensive reactions to optical collision. *Infant Behavior and Development*, *17*, 165–174.
- Nelson, K. (1973). Some evidence for the cognitive primacy of categorization and its functional basis. *Merrill-Palmer Quarterly*, *19*, 21–39.
- Oakes, L. M., & Cohen, L. B. (1990). Infant perception of a causal event. *Cognitive Development*, *5*, 193–207.
- Oakes, L. M., & Cohen, L. B. (1995). Infant causal perception. In C. Rovee-Collier & L. P. Lipsitt (Eds.), *Advances in infancy research* (Vol. 9, pp. 1–54). Norwood, NJ: Ablex.
- Oviatt, S. L. (1980). The emerging ability to comprehend language: An experimental approach. *Child Development*, *51*, 97–106.
- Oviatt, S. L. (1982). Inferring what words mean: Early development in infants' comprehension of common object names. *Child Development*, *53*, 274–277.
- Poulin-Dubois, D. (1999). Infants' distinction between animate and inanimate objects: The origins of naïve psychology. In P. Rochat (Ed.), *Early social cognition: Understanding others in the first months of life* (pp. 257–280). Hillsdale, NJ: Erlbaum.
- Poulin-Dubois, D., & Héroux, G. (1994). Movement and children's attributions of life properties. *International Journal of Behavioral Development*, *17*, 329–347.
- Poulin-Dubois, D., Lepage, A., & Ferland, D. (1996). Infants' concept of animacy. *Cognitive Development*, *11*, 19–36.
- Poulin-Dubois, D., & Shultz, T. R. (1988). The development of understanding of human behavior: From agency to intentionality. In J. W. Astington, P. L. Harris, & D. R. Olson (Eds.), *Developing theories of mind* (pp. 109–125). Cambridge, England: Cambridge University Press.
- Premack, D. (1990). The infants' theory of self-propelled objects. *Cognition*, *36*, 1–16.
- Premack, D. (1991). The infant's theory of self-propelled objects. In D. Frye & C. Moore (Eds.), *Children's theories of mind: Mental states and social understanding* (pp. 39–48). Hillsdale, NJ: Erlbaum.
- Quinn, P. C., & Eimas, P. D. (1996). Perceptual organization and categorization. In C. Rovee-Collier & L. Lipsitt (Eds.), *Advances in infancy research* (Vol. 10, pp. 1–36). Norwood, NJ: Ablex.
- Quinn, P. C., & Eimas, P. D. (1997). A reexamination of the perceptual-to-conceptual shift in mental representations. *Review of General Psychology*, *1*, 271–287.
- Quinn, P. C., Johnson, M., Mareschal, D., Rakison, D., & Younger, B. (2000). Response to Mandler and Smith: A dual process framework for understanding early categorization? *Infancy*, *1*, 111–122.
- Rakison, D. H. (2000). When a rose is just a rose: The illusion of taxonomies in infant categorization. *Infancy*, *1*, 77–90.
- Rakison, D. H., & Butterworth, G. (1998a). Infant attention to object structure in early categorization. *Developmental Psychology*, *34*, 1310–1325.
- Rakison, D. H., & Butterworth, G. (1998b). Infants' use of parts in early categorization. *Developmental Psychology*, *34*, 49–62.
- Rakison, D. H., & Cohen, L. B. (1999). Infants' use of functional parts in basic-like categorization. *Developmental Science*, *2*, 423–432.
- Rakison, D. H., & Poulin-Dubois, D. (2000a, July). *Infants' understanding of animate and inanimate events*. Paper presented at the 12th biannual International Conference on Infant Studies, Brighton, England.
- Rakison, D. H., & Poulin-Dubois, D. (2000b, July). *You go this way and I'll go that way: Infants' attention to correlations among object parts and motion path*. Poster presented at the 12th biannual International Conference on Infant Studies, Brighton, England.
- Richards, D. D., & Siegler, R. S. (1986). Children's understanding of the attributes of life. *Journal of Experimental Child Psychology*, *42*, 1–22.
- Ricciutti, H. (1965). Object grouping and selective ordering behaviour in infants 12 to 24 months old. *Merrill-Palmer Quarterly*, *11*, 129–148.
- Roberts, K. (1998). Linguistic and nonlinguistic factors influencing infant categorization: Studies of the relationship between cognition and language. In C. Rovee Collier & L. P. Lipsitt (Eds.), *Advances in infancy research* (Vol. 11, pp. 45–107). London: Ablex.
- Rochat, P. (Ed.). (1999). *Early social cognition: Understanding others in the first months of life*. Hillsdale, NJ: Erlbaum.
- Rochat, P., Morgan, R., & Carpenter, M. (1997). Young infants' sensitivity to movement information specifying social causality. *Cognitive Development*, *12*, 441–465.
- Rochat, P., Neisser, U., & Marian, V. (1998). Are young infants sensitive to interpersonal contingency? *Infant Behavior and Development*, *21*, 355–366.
- Rochat, P., & Striano, T. (1999). Social cognitive development in the first year. In P. Rochat (Ed.), *Early social cognition: Understanding others in the first months of life* (pp. 257–280). Hillsdale, NJ: Erlbaum.
- Rosch, E. (1978). Principles of categorization. In E. Rosch & B. Lloyd (Eds.), *Cognition and categorization* (pp. 27–48). Hillsdale, NJ: Erlbaum.
- Rosch, E., Mervis, C. B., Gray, W. D., Johnson, D. M., & Boyes-Braem, P. (1976). Basic objects in natural categories. *Cognitive Psychology*, *8*, 382–439.
- Saffran, J. R., Johnson, E. K., Aslin, R. N., & Newport, E. L. (1999). Statistical learning of tone sequences by human infants and adults. *Cognition*, *70*, 27–52.
- Saffron, E. M., & Schwartz, M. F. (1994). Of cabbages and things: Semantic memory from a neuropsychological perspective—A tutorial review. In C. Umiltà & M. Moscovitch (Eds.), *Attention and performance XV: Conscious and unconscious information processing* (Vol. 3, pp. 507–536). Cambridge, MA: MIT Press.
- Schlottman, A., & Surian, L. (1999). Do 9-month-olds perceive causation-at-a-distance? *Perception*, *28*, 1105–1113.
- Sharp, K. C., Candy-Gibbs, S., Barlow-Elliott, L., & Petrun, C. J. (1985).

- Children's judgement and reasoning about aliveness: Effects of object, age, and cultural/social background. *Merrill-Palmer Quarterly*, 31, 47–65.
- Simons, D. J., & Keil, F. C. (1995). An abstract to concrete shift in the development of biological thought: The insides story. *Cognition*, 56, 129–163.
- Slater, A. (1989). Visual memory and perception in early infancy. In A. Slater & G. Bremner (Eds.), *Infant development* (pp. 43–72). Hove, England: Erlbaum.
- Slater, A. (1997). Visual perception and its organization in infancy. In G. Bremner, A. Slater, & G. Butterworth (Eds.), *Infant development: Recent advances* (pp. 31–53). Hove, UK: Psychology Press.
- Slater, A., & Butterworth, G. (1997). Perception of social stimuli: Face perception and imitation. In G. Bremner, A. Slater, & G. Butterworth (Eds.), *Infant development: Recent advances* (pp. 223–246). Hove, England: Psychology Press.
- Soja, N. N., Carey, S., & Spelke, E. S. (1991). Ontological categories guide young children's inductions of word meaning: Object terms and substance terms. *Cognition*, 38, 179–211.
- Spelke, E. S., Breinlinger, K., Macomber, J., & Jacobson, K. (1992). Origins of knowledge. *Psychological Review*, 99, 605–632.
- Spelke, E. S., Phillips, A., & Woodward, A. L. (1995). Infants' knowledge of object motion and human action. In D. Sperber, D. Premack, & A. J. Premack (Eds.), *Causal cognition* (pp. 150–184). Oxford, England: Clarendon.
- Springer, K., & Keil, F. C. (1991). Early differentiation of causal mechanisms appropriate to biological and nonbiological kinds. *Child Development*, 62, 767–781.
- Stewart, W. (1984, November). *Object motion and the perception of animacy*. Paper presented at the Psychonomic Society Meeting, San Antonio, TX.
- Thelen, E., & Smith, L. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press/Bradford Books.
- Tomasello, M. (1995). Joint attention as social cognition. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 103–130). Hillsdale, NJ: Erlbaum.
- Tomasello, M., Strosberg, R., & Akhtar, N. (1996). Eighteen-month-old children learn words in non-ostensive contexts. *Journal of Child Language*, 23, 157–176.
- Van de Walle, G. A., & Hoerger, M. L. (1996, April). *Perceptual foundations of categorization in infancy*. Poster session presented at the International Conference on Infant Studies, Providence, RI.
- Watson, J. S. (1985). Contingency perception in early social development. In T. M. Field & N. A. Fox (Eds.), *Social perception in infants* (pp. 157–176). Norwood, NJ: Ablex.
- Wellman, H. M. (1990). *The child's theory of mind*. Cambridge, MA: MIT Press.
- Wellman, H. M. (1993). Early understanding of mind: The normal case. In S. Baron-Cohen, H. Tager-Flusberg, & D. J. Cohen (Eds.), *Understanding other minds: Perspectives from autism* (pp. 10–39). Oxford, England: Oxford University Press.
- Werker, J. F., Cohen, L. B., Lloyd, V. L., Casasola, M., & Stager, C. L. (1998). Acquisition of word-object associations by 14-month-old infants. *Developmental Psychology*, 34, 1289–1309.
- Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition*, 69, 1–34.
- Woodward, A. L. (1999). Infants' ability to distinguish between purposeful and non-purposeful behaviors. *Infant Behavior and Development*, 22, 145–160.
- Woodward, A. L., & Sommerville, J. A. (2000). Twelve-month-old infants interpret action in context. *Psychological Science*, 11, 73–77.
- Woodward, A. L., Sommerville, J. A., & Guajardo, J. J. (in press). How infants make sense of intentional action. In B. Malle, L. Moses, & D. Baldwin (Eds.), *Intentionality: A key to human understanding*. Cambridge, MA: MIT Press.
- Younger, B. A. (1985). The segregation of items into categories by ten-month-old infants. *Child Development*, 56, 1574–1583.
- Younger, B. A. (1993). Understanding category members as "the same sort of thing": Explicit categorization in ten-month infants. *Child Development*, 64, 309–320.
- Younger, B. A., & Cohen, L. B. (1986). Developmental change in infants' perception of correlations among attributes. *Child Development*, 57, 803–815.
- Zeedyk, M. S. (1996). Developmental accounts of intentionality: Toward integration. *Developmental Review*, 16, 416–461.

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