Infants' Knowledge of the Association Between Object Kinds and Motion Cues

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ABSTRACT

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The origin in infancy of the distinction between animate beings (animals and humans), and inanimate objects (vehicles, furniture, etc.) is a research topic of theoretical and empirical interest. One recent proposal is that infants form concepts of animate beings and inanimate objects on the basis of motion cues. In the present experiments, infants' ability to associate motion cues with animals and vehicles was tested. The motion cues of line of motion trajectory and type of motion onset were tested in four experiments. Line of motion trajectory was depicted using bouncing as the inanimate trajectory and jumping as the animate trajectory. Type of motion onset was depicted using externally caused motion onset as the inanimate onset and self-initiated motion onset as the animate onset. In each experiment, infants were presented with animated events using an infant-controlled habituation procedure. In the habituation phase, infants saw an animal performing an animate motion cue and a vehicle performing an inanimate motion cue. In the test phase, the habituation-phase pairing of category and motion cue was maintained in one event and broken in the other event. In Experiment 1, 12-, 16-, and 20-month-olds were tested on their ability to associate trajectory and object kind under stringent conditions in which the animals' legs' and the vehicles' wheels did not move. Only 20-month-olds showed a robust ability to associate trajectory and category. In Experiment 2, 16-month-olds' ability to associate trajectory and category was not facilitated by more ecologically valid events in which the animals' legs and the vehicles' wheels moved and the animate features of the jumping trajectory were increased. In Experiment 3, 16-

month-olds did not associate motion onsets and category. In Experiment 4, 16-month-olds were unable to associate these particular motion onsets with individual animals and vehicles, suggesting that infants were unable to discriminate between these particular types of motion onset. The present research indicates infants are able to associate trajectory with animals and vehicles by 20 months. Directions for future research are discussed, including techniques for further examining the integration of motion into infants' concepts.

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CHAPTER 1: INTRODUCTION

One fundamental cognitive ability is to distinguish between animate beings--that is, animals--and inanimate objects--that is, artefacts, rocks, and plants (Rakison & Poulin-Dubois, 2001). Knowing an entity's animate or inanimate category membership is central to one's reasoning about that entity because it affords different types of inferences and causal explanations. For example, animate beings possess biological and mental properties, but inanimate objects do not (see R. Gelman & Spelke, 1981, for a detailed analysis of adults' perspectives on the differences between animate objects, specifically people, and inanimate objects). In addition, the fundamental nature of the animate-inanimate distinction is suggested by reports of neuroanatomical correlates for knowledge of these categories (Caramazza & Shelton, 1998; Gainotti, 2000; Garrard et al., 2001).

Developmental research has established that the animate-inanimate distinction is an important conceptual distinction by the preschool years (S. A. Gelman & Opfer, 2002). For example, preschoolers determine quite accurately whether animals and objects are alive, attribute biological processes to humans and not to objects (S. A. Gelman & Opfer, 2002), and use animacy cues to interpret words (Backscheider, Gelman, Martinez, & Kowieski, 1999). Due to the centrality of the animate-inanimate distinction to human cognition and preschoolers' well-developed conceptual understanding of this distinction, it is of empirical and theoretical interest to study its developmental origins in infancy. In the present experiments, I tested whether infants have a basic understanding of the animate-inanimate distinction, specifically whether they possess knowledge of the motion properties associated with these object kinds.

One prominent view of the developmental origins of the animate-inanimate distinction is that infants distinguish between animate beings and inanimate objects by attending to motion cues. In two papers which sparked particular interest among infancy researchers, Mandler (1992a, 1992b, see also Mandler, 2000a) argued that infants develop concepts of animate beings and inanimate objects by using *perceptual analysis* (Mandler, 1988), a representational process via which perceived motion cues are recoded into simpler, abstract representations called *image schemas*. These image schemas are then combined to form concepts. For example, according to Mandler, an infant's concept of an animate being might combine image schemas of self-propelled motion, moving along an irregular trajectory, and interacting contingently with other entities at a distance. Rakison and Poulin-Dubois (2001) expanded upon Mandler's ideas by proposing a more detailed typology of the motion cues that may be associated with animate and inanimate objects in infancy. Motion cues associated with animate beings include: (a) self-propelled motion onset, (b) irregular line of trajectory, (c) action that is produced at a distance, (d) highly contingent motion, and (e) role of agent in causal interactions. Motion cues associated with inanimate objects include: (a) caused motion onset, (b) smooth line of trajectory, (c) action produced only by contact, (d) non- or perfectly contingent motion, and (e) role of recipient in causal interactions. Based on their comprehensive review of the literature, Rakison and Poulin-Dubois (2001) concluded that there is evidence that infants can discriminate between the animate and inanimate forms of most of these cues, but that little is known about infants' ability to associate different forms of motion cues with the categories of animate beings and inanimate objects.

An alternate view of the origins of the animate-inanimate distinction has been presented, primarily by Quinn and Eimas (Eimas, 1994; Quinn & Eimas, 1996, 2000; Quinn, Johnson, Mareschal, Rakison, & Younger, 2000; Rakison, 2000). Quinn and Eimas argue that infants' categories, including the animate-inanimate distinction, are formed via attention to perceptual features. Specifically, they argue that infants attend to the presence, absence, and specific form of perceptual features, as well as to the co-variation among perceptual features. In this view, an associative process forms perceptual and conceptual categories. With time, enrichment of early perceptual categories produces conceptual understanding. These researchers argue that global categories, such as animate beings and inanimate objects, have distinctive features that are highly discriminable and frequently encountered (Quinn & Eimas, 1996) and that therefore these categories develop early in infancy. They agree with Mandler that motion is an important feature of infants' animate-inanimate distinction, but they argue for an important role for other perceptual features in infants' early category of animals (e.g., presence or absence of legs, wheels, facial features; Quinn & Eimas, 1996). Quinn and Eimas' view differs from Mandler's view in several ways. First, Quinn and Eimas argue that perceptual and conceptual categories are formed via the same mechanism, quantitative enrichment, whereas Mandler argues that these two categories are formed by different mechanisms. Mandler (1998, 2000a) argues that perceptual categories are formed automatically by accumulating perceptual features, whereas conceptual categories are formed actively using perceptual analysis to extract abstract schemas of what something does (e.g., how it moves). Second, Quinn and Eimas argue that infants' categories are perceptual, whereas Mandler argues that both types of categories are present in infancy and interprets existing data as providing evidence of perceptual categories as young as 3 months of age and conceptual categories at 7 months of age (e.g., Mandler, 2000a). Indeed, Quinn and Eimas argue that infants' knowledge is all perceptually derived and that infants' knowledge that has been considered conceptual is not qualitatively different from the knowledge that is perceptual (Quinn & Eimas, 1996). Third, Quinn and Eimas argue for the importance of multiple cues in infants' animate-inanimate category distinction, whereas Mandler argues for the foundational importance of motion.

Several lines of evidence support the plausibility of the proposal that infants may use motion to form the categories of animate beings and inanimate objects (but see R. Gelman, Durgin, & Kaufman, 1995, regarding the limitations of motion as a cue). First, motion attracts the attention of even very young infants. For example, infants of 2 to 3 months of age prefer to look at moving rather than stationary objects (Kellman & Banks, 1998). Second, the distinctiveness of 1- to 2-month-olds' reactions to a person and an inanimate object (a doll) are increased by activity (Cossette, Duhamel, Léveillé, & Gaudreau, 1999). Specifically, infants smile and vocalize more at a person than a doll and this difference is greater when the person or doll produces actions and sounds than when the person or doll is motionless and silent. Third, when presented with point-light displays of the pendular motion of multiple exemplars of animals walking in place or the rotary motion of multiple exemplars of vehicles rolling in place, infants of 3 and 6 months will extract motion commonalities across category exemplars (Arterberry & Bornstein, 2001, 2002). Fourth, the neurological evidence suggests that there are distinct neuroanatomical correlates associated with the visual perception of biological and non-biological (rigid) motion (Grèzes et al., 2001; Grossman et al., 2000; Grossman & Blake, 2001). Fifth, preschoolers have been found to link motion with life. For example, preschoolers expect animals and objects to move differently (Massey & Gelman, 1988) and explain differently motion by animate and inanimate objects (S. A. Gelman & Gottfried, 1996). This link is so strong that 5-year-olds will attribute the properties of a living being (e.g., hunger, memory) to an artificial stimulus of ambiguous identity (a "blob") that moves in an animate, but not an inanimate manner (Poulin-Dubois & Héroux, 1994).

Researchers have also found that adults will describe the motion of a "blob" or a simple geometric shape as being like that of a living being or a non-living object. Poulin-Dubois & Héroux (1994) found that any type of motion was associated with attributions of life by adults, but that only certain types of motion were associated with attribution of biological properties. Stewart (1984) asked adults whether they thought a disc moved like a living being, like a non-living object, or they couldn't tell. She found that adults consistently rated certain types of motion as like a living being and other types of motion as like a non-living object. For example, she found that 73% of adults rated motion onset caused by a lever push as moving like a non-living object, 12% rated it is as moving like a living being, and 15% were undecided. In contrast, 30% of adults rated apparently self-initiated motion with no lever present as moving like a non-living object, 50% rated it as moving like a living being, and 30% were undecided. In addition, 85% of adults rated a trajectory that approached a barrier at an angle, impacted the barrier, and reflected at the same angle as moving like a non-living object. In contrast, the same trajectory without impacting the barrier, which produced the impression of avoidance, was rated by 80% of adults as moving like a living being. It should be noted, however, that when a separate group of adults were presented with the avoidance and self-initiated motion events and were given the option of classifying the movement as a mechanized object, they were more likely to rate both events as a mechanized object, rather than a person or animal. In addition, analysis of descriptive responses collected by Stewart and further experiments by R. Gelman et al. (1995) suggest that the link between motion cues and attributions of animacy is not one-to-one; rather attributions may be influenced by such things as task instructions and the environment in which the trajectory occurs. Tremoulet and Feldman (2000) found that a when a dot or rectangle moved on a featureless background and there was a simultaneous change in speed and direction of motion, adults rated the dot or rectangle as likely to be alive. Again, features other than motion did play a role, in that ratings were influenced by the degree to which the rectangle was aligned with the direction of motion. Overall, the data suggest that motion cues influence whether adults interpret the motion of an unfamiliar or simple shape as being like a living being, or like a non-living object.

Given the evidence that preschoolers and adults will make attributions about a simple shape based on motion cues, the evidence that preschoolers understand that animate and inanimate objects differ in at least certain ways in their motion characteristics, and the theoretical proposal that motion is central to infants' grasp of the animate-inanimate distinction, researchers have begun to study whether infants possess a simple animate-inanimate distinction and whether this distinction includes knowledge of motion. To determine whether infants discriminate between animate and inanimate objects, researchers have studied whether infants recognize that items varying in appearance belong to the same category (e.g., an elephant, a rabbit, and a robin are all animals). A number of studies have used the object-manipulation paradigm, in which infants are presented simultaneously with several small replicas of members of two categories. Evidence of categorization is obtained if infants touch more members of a given category in sequence than would be expected by chance, or if separate sequences of touches to category members are more frequent than would be expected by chance. Using this paradigm, infants aged 14 to 30 months have been found to categorize animals and vehicles (Mandler & Bauer, 1988; Mandler, Bauer, & McDonough, 1991; Rakison & Butterworth, 1998a, 1998b).

To test categorization in younger infants, researchers have used the object-examination task developed by Ruff (1986) in which small replicas are presented sequentially and the duration of infants' examining of each replica is recorded. First, infants are presented with several members of one category. Then, in the test phase, infants are presented with a novel member of the category and a member of the contrasting category. Evidence of categorization is obtained if infants examine the contrasting-category member longer than they examine the novel same-category member. Mandler and McDonough (1993) used this procedure and found that infants as young as 9 months categorize animals and vehicles. Converging results were obtained by Oakes, Coppage, and Dingel (1997) with 10-month-olds.

Recently, the visual habituation procedure has been used to examine young infants' ability to categorize animals and vehicles (Arterberry & Bornstein, 2001, 2002). This procedure is similar to the object-examining task described above except that the stimuli are two-dimensional (pictures or movies) and the dependent variable is infants' looking time. Using this procedure, Arterberry and Bornstein (2001, 2002) presented infants with static images of multiple exemplars of a category until their looking time dropped to a criterion. Infants were then presented with a new member of that category and a member of another category. These researchers found that infants of 3 and 6 months of age will categorize animals and vehicles. In another experiment (Arterberry & Bornstein, 2002), these researchers found that when infants of 9 months are habituated to point-light displays of multiple exemplars of animals walking in place or multiple exemplars of vehicles rolling in place and are then presented with a static images of an animal and a vehicle, infants will abstract common attributes from the dynamic displays and generalize them to the static displays. Nine-month-old infants are unable to generalize from static cues to dynamic cues, however, and younger infants are unable to make either dynamic to static or static to dynamic generalizations.

These studies on infant categorization suggest that as young as 3 months infants can perceive within-category similarity and between-category dissimilarity based on the static and dynamic cues of animals and vehicles. At the youngest ages of 3 and 6 months there is little debate that infants classify category members based on perceptual cues (Arterberry & Bornstein, 2001; Mandler, 2000a; Quinn & Eimas, 1996). At the older ages, however, it is not entirely clear whether these global categories are of a conceptual nature (e.g., Mandler, 2000a, 2000b; Mandler & McDonough, 1993; Quinn & Eimas, 1996, 2000; Quinn et al., 2000; Rakison & Butterworth, 1998b). Stronger evidence that infants possess conceptual knowledge of animals and vehicles was obtained in a recent series of studies using a generalized imitation task. In these studies (Mandler & McDonough, 1996; McDonough & Mandler, 1998), infants are presented with one exemplar from each of the two categories (e.g., a cat and a bus) and a prop (e.g., a cup) and a baseline measure of behaviour is taken. The experimenter then models an action with another member of one category, for example, a dog drinking from the cup. The infants are then given the two exemplars and the prop and the frequency with which they perform the action with each exemplar is recorded. Mandler and McDonough (1996) tested infants' generalization of category-appropriate activities, specifically drinking and sleeping for animals and transporting and starting with a key for vehicles. They found that 14-month-old infants generalized category-appropriate activities based on category membership and limited induction based on object kind. With a simplified procedure and an opportunity to imitate prior to the generalization task, 9- and 11-month-olds also selected the category match during the generalization phase (McDonough & Mandler, 1998). These studies provide the first evidence that infants' categories of animals and vehicles have a conceptual component, specifically activities. They do not, however, address Mandler's proposal that infants' concepts of animals and objects are based on motion cues.

To begin to address this issue, I conducted two series of experiments in which I investigated infants' ability to associate two types of motion cues, line of trajectory and type of motion onset, with object kinds. Specifically, in one series of experiments I tested infants' ability to associate a non-linear (or irregular) trajectory, jumping over an obstacle, with animals and a linear (or smooth) trajectory, hitting an obstacle and bouncing back, with vehicles. In the other series of experiments, I tested infants' ability to associate a self-initiated motion onset with animals and an externally caused motion onset with vehicles. I used non-human animals to represent animate beings and vehicles to represent inanimate objects because researchers have frequently contrasted non-human animals and vehicles when testing infant categorization. Furthermore, virtually all existing research examining infants' association of motion cues to object kinds has used humans to represent animate beings and objects other than vehicles to represent inanimate objects.

Line of Trajectory

Trajectory is a promising candidate as a basis of infants' conceptual animate-inanimate distinction for several reasons. First, information about an object's trajectory will frequently be directly observable at a variety of time points as an object moves, increasing the probability that infants attend to this cue. Second, even very young infants show good discrimination between trajectories. For example, using point-light displays, 3- and 5-month-old infants have been shown to discriminate between a pattern of light trajectories typical of a walking person in place and a scrambled version of the same light trajectories (Bertenthal, Haith, & Campos, 1983).

More relevant for the present research is whether infants discriminate between different object trajectories as an object translates in space, particularly for linear and non-linear trajectories. Sharon and Wynn (1998) tested whether 6-month-olds discriminate between jumping and falling using a familiarization procedure. Infants' looking time was longer for events with a novel trajectory than for events with a familiar trajectory, indicating that the infants discriminated between the two trajectories. Research using head tracking and reaching has also shown that 6-month-olds expect objects to follow a linear path (von Hofsten, Vishton, Spelke, Feng, & Rosander, 1998) and are able to learn that a particular object will follow either a linear or a non-linear trajectory (von Hofsten, Feng, & Spelke, 2000). Thus, there is evidence that even very young infants are sensitive to an object's trajectory, both in terms of the relative trajectory of an object's parts and in terms of the trajectory of the object as a whole. Most pertinently for the present studies, young infants discriminate between a non-linear or jump-like trajectory and another line of trajectory.

The only experiment to date examining infants' ability to associate object kinds with trajectories was conducted concurrently with the present experiments and used the generalized imitation paradigm. Poulin-Dubois and Vyncke (2002) tested 14- and 18-month-olds' ability to associate animals and vehicles with two animate motions (climbing stairs, jumping over a block) and two inanimate motions (jumping across a gap, sliding up and down a U-shaped ramp). Infants' use of the appropriate exemplar increased significantly from baseline to generalization. Furthermore, infants used the appropriate exemplar more than the inappropriate exemplar in the generalization phase, but not in the baseline phase. These patterns of behaviour indicate that infants generalized motion trajectory from one category exemplar to members of the same object kind. When the tasks were considered separately, variability in infants' performance was found. For example, only 18-month-olds correctly generalized jumping over a block to animals. These results are exciting, but there are some caveats. First, collapsing across the two age groups, infants did not perform a measurable action on 36% of the trials in the generalization phase. Furthermore, collapsing across baseline and generalization phases, 14-month-olds performed actions on fewer trials than 18-month-olds. These results suggest that it would be valuable to conduct additional research assessing infants' knowledge using a different methodology.

Motion Onset

Motion onset was considered a promising candidate as a basis of infants' conceptual animate-inanimate distinction for several reasons. First, a number of researchers have theorized that the distinction between self-initiated and caused motion onset is central to the animate-inanimate distinction (Mandler, 1992b; Poulin-Dubois, Lepage, & Ferland, 1996; Rakison & Poulin-Dubois, 2001). Second, the distinction between self-initiated and caused motion has also been argued to be central to the perception of intentionality (Premack, 1990), which is a precursor of a theory of mind; theory of mind is a critical feature of humans but not of inanimate objects (e.g., R. Gelman & Spelke, 1981; Poulin-Dubois, 1999). Specifically, Premack (1990) has argued that infants interpret self-initiated motion as intentional. Third, from birth infants are exposed in daily life both to frequent instances of self-initiated motion by humans when their parents and other people move around them, and to frequent instances of caused motion when their parents and other people pick-up (Leslie, 1982, 1984a), carry, push, or pull furniture and other objects.

Research is lacking on infants' ability to discriminate self-initiated versus externally caused motion, but relevant research exists on infants' ability to detect physical causality and to detect action at a distance (Rakison & Poulin-Dubois, 2001). By the middle of the first year, infants understand that a hand must be in contact with an object in order to move the object (Leslie, 1984a). Research by Leslie (1984b) indicates that 6.5-month-old infants discriminate between a causal event in which there is contact between two different coloured blocks (direct launching event) and non-causal events in which there is no contact between the blocks (launching without collision and delayed-reaction without collision). In the direct launching event, a red brick moved and contacted a stationary green brick after which the green brick began to move immediately and the red brick stopped moving. In the launching without collision event there was a spatial gap between the two blocks. In the delayed-reaction-without-collision event there was both a spatial gap between the two blocks and a temporal gap between when the red brick stopped and the green brick started. These results have been replicated with 7-month-olds using circles instead of blocks (Oakes, 1994). When real objects were used and 6- and 10-month-olds were tested, however, only the 10-month-olds discriminated between causal events with contact and the non-causal events without contact (Oakes & Cohen, 1990). That 6-month-olds discriminated between causal events with contact and non-causal events without contact when these events were depicted using geometric figures, whereas infants of the same age did not discriminate between such events when they were depicted using real objects, suggests that 6-month-olds' ability to discriminate between such events is not robust. Thus, there is indirect evidence that by 6 months, the ability to discriminate between self-initiated motion and externally caused motion is beginning to appear and that this ability is robust by 10 months of age. Researchers have also found that 9-month-old infants treat a causal interaction at a distance between non-rigid shapes (a chase sequence) differently from similar displays in which there is a pause between the movements of the two shapes (Schlottmann & Surian, 1999). These data indicate that by 9 months infants discriminate between causal interactions that occur without contact and non-causal interactions that occur without contact.

A few experiments have been conducted to examine infants' understanding that type of motion onset is associated with object kind. Golinkoff and Harding (1980, as cited in Golinkoff, Harding, Carlson, & Sexton, 1984) measured 16- and 24-month-old infants' reactions when a chair in the testing room seemed to move by itself as the result of a hidden person pulling the chair using clear plastic wires. Less than half of 16-month-olds and most 24-month-olds showed that they found this event to be anomalous, in the form of expressions of surprise, fear, or laughter. The authors concluded that by the end of the second year infants expect certain actions but not others of inanimate objects, but they caution that research with other inanimate objects is needed (Golinkoff et al., 1984). Furthermore, based on the experiment description, it appears that infants' reactions were not gauged against a baseline condition. A possible baseline condition would be a chair moving in a category appropriate manner, such as moving after being pushed by a person.

Poulin-Dubois et al. (1996) compared 9- and 12-month-olds' responses to self-initiated motion by a person and one type of inanimate object, a robot. They compared infants' reactions to a stationary and self-initiated robot and to a stationary and self-initiated person. They found that infants' negative affect was higher in the self-initiated robot condition than in the stationary robot condition. In contrast, no difference in negative affect was found between the self-initiated person condition and the stationary person condition. These data suggest that by 9 months of age infants find anomalous self-initiated motion by one type of inanimate object.

Woodward, Phillips, and Spelke (1993, as cited by Spelke, Phillips, & Woodward, 1995) tested whether 7-month-olds expect contact or no contact interactions between two objects and between two people. They presented one group of infants with events in which a rectangular object moved behind a barrier and after a delay a partially-hidden second object emerged from behind the other end of the barrier. In the test phase, the barrier was removed and infants saw an event in which the two objects made contact and an event in which the objects did not make contact. A second group of infants were presented with events featuring people instead of objects. Infants in the object condition, but not the human condition, looked longer at the no contact events than at the contact events. The authors argue that infants were surprised to see inanimate objects interact without contact. This interpretation is weakened, however, by the fact that infants' preference for the no contact inanimate-object event over the contact inanimate-object event was only marginally greater than in a baseline condition in which infants saw only the test events.

It is important for several reasons to collect further data on infants' knowledge of the type of motion onset that is appropriate for different object kinds. As Rakison and Poulin-Dubois (2001) have pointed out, the existing research on infants' association of object kind and type of motion onset used humans as the exemplar of animate beings. In addition, a limited range of inanimate objects has been used as exemplars. Furthermore, in the experiment with the most thorough controls and the most detailed available description (Poulin-Dubois et al., 1996), the type of inanimate object--a robot--was novel to the infants, whereas the type of animate being--a human--was not. Finally, the details of two of the three experiments are not available as they are described in a conference proceeding (Golinkoff et al., 1984) and a chapter (Spelke et al., 1995). Thus, it would be valuable to conduct additional research testing infants' knowledge of the link between type of motion onset and object kind using animate beings other than humans and a wider range of inanimate objects.

The Present Experiments

In the present test of infants' ability to associate animate beings and inanimate objects with motion cues, I used an infant-controlled habituation paradigm (Horowitz, Paden, Bhana, & Self, 1972) to test 12- to 20-month-old infants' ability to associate motion cues with object kinds. The habituation paradigm uses infants' preference for novelty (Fantz, 1964) to assess their perceptual and cognitive abilities (Haith & Benson, 1998), including their ability to detect anomalous events (e.g., Baillargeon, 1995). In this paradigm, there are two phases: the habituation phase and the test phase. In the habituation phase, infants are presented with repeated exposures of an event until their visual fixation to the event drops to a criterion level. At this point, the experiment proceeds to the test phase in which infants are typically presented with two events. One test event has the same feature of experimental interest as the event in the habituation phase. The other event differs from the habituation event in the feature of interest. If infants detect the change in the latter type of event, they will look longer at this event than at the former type of test event (Quinn & Eimas, 1996). The infant-controlled habituation procedure, using looking time as the dependent variable, has been successfully used to test the cognitive abilities of infants as young as 3 months (e.g., Baillargeon, 1995). The visual habituation procedure has a number of features which make it attractive for use with younger infants including limited demands in terms of active participation by the infant (Mandler & Bauer, 1988; Oakes, Madole, & Cohen, 1991), reduced motor demands compared to paradigms using three-dimensional replicas, and individual tailoring of the length of each testing session (see also Kellman & Arterberry, 1998).

Infants were presented repeatedly with an event in which an animal performed an animate form of a motion cue (e.g., a dog jumped over a wall) and an event in which a vehicle performed an inanimate form of a motion cue (e.g., a car hit a wall and rebounded). When an infant's looking time dropped to a criterion, test trials were presented featuring a new animal or a new vehicle. There were two types of test events: the congruent event and the incongruent event. In the congruent event, the habituation-phase pairing of category and motion cue was maintained. In the incongruent event, the pairing was broken (e.g., a vehicle jumped over the wall). If infants associate the category and the form of motion cue then they should detect the break in association in the incongruent event and look longer at the incongruent event than at the congruent event. Thus, I used a modified form of Cohen's switch design (e.g., Younger & Cohen, 1986). A control event that was dissimilar to the experimental stimuli was presented at the beginning and end of the testing session (Werker, Cohen, Lloyd, Casasola, & Stager, 1998) to determine whether fatigue interfered with infants' performance.

Four experiments were conducted using this general procedure. I used familiar animals and vehicles as category exemplars. In Experiments 1 and 2, I tested infants' ability to associate trajectory and object kind using exemplars of mammals and vehicles. In Experiment 1, the legs and wheels of the exemplars were static to prevent infants from making a simple association between moving parts and trajectories. In Experiment 2, moving parts were added to the category exemplars and the jumping trajectory was modified to enhance the ecological validity of the events. In Experiment 3, I tested infants' ability to associate type of motion onset and object kinds. The category exemplars of animals and vehicles had moving parts. In Experiment 4, I used the stimuli from Experiment 3 to test infants' ability to associate type of motion onset with a specific object or animal.

CHAPTER 2: INFANTS' KNOWLEDGE OF THE ASSOCIATION BETWEEN OBJECT KIND AND LINE OF TRAJECTORY

Experiment 1

In Experiment 1, I assessed the ability of 12-, 16-, and 20-month-old infants to associate a jumping trajectory with animals and a bouncing trajectory with vehicles. The exemplars of animals and vehicles had static legs and wheels respectively to prevent infants from using moving parts as a basis for association with trajectory. I hypothesized that the ability to associate trajectory and object kind would emerge between the ages of 12 and 16 months. This hypothesis was based on three pieces of evidence. First, 6-month-olds discriminate between a jumping trajectory and another trajectory (Sharon & Wynn, 1998). Second, using a habituation procedure, infants as young as 10 months have been found to associate visual attributes in a categorical context (Younger & Cohen, 1983, 1986). Third, the age at which infants have been found to categorize animals and vehicles has varied considerably. Even considering only experiments for which researchers have argued that a conceptual basis underlies categorization, the range is still from 9 to 14 months. Given that some components of the ability to associate lines of trajectory with animals and vehicles emerge during the second half of the first year and other components may emerge later, I hypothesized that infants' association of trajectory and object kind would emerge early in the second year of life.

Method

Participants

A total of 120 full-term infants participated in this study. The languages spoken in the infants' homes included English, French, or both English and French. The infants had no vision or hearing impairments, based on parent reports. The 12-month-old age group consisted of 41 infants (21 boys, 20 girls; *M* = 12.32 months, *SD* = 0.22). Of these infants, 17 were excluded from the analysis due to the habituation criterion not being met (4 boys, 1 girl), low looking times at the test trials (1 boy, 1 girl), fussiness (1 boy, 1 girl), technical problems (1 boy), or experimenter error (3 boys, 4 girls). The final sample consisted of 24 infants (11 boys, 13 girls; mean age = 12.30 months; *SD* = 0.28). The 16-month-old age group consisted of 43 infants (20 boys, 23 girls; *M* = 16.15 months, *SD* = 0.23). In total, 19 of these infants were excluded from the analysis due to the habituation criterion not being met (1 boy, 1 girl), low looking times at the test trials (1 boy, 2 girls), fussiness (2 boys, 4 girls), technical problems (1 boy, 3 girls), or experimenter error (1 boy, 3 girls). The final sample consisted of 24 infants (14 boys, 10 girls; mean age = 16.18 months; *SD* = 0.23). The 20-month-old age group consisted of 36 infants (19 boys, 17 girls; *M* = 20.20 months, *SD* = 0.18). Twelve infants were excluded from the analysis due to the habituation criterion not being met (2 boys, 2 girls), fussiness (1 boy, 3 girls), technical problems (1 girl), experimenter error (2 boys), or parental interference (1 girl). The final sample consisted of 24 infants (14 boys, 10 girls; mean age = 20.17 months; *SD* = 0.18). As measured by parents' highest level of education, families represented a range of socio-economic backgrounds, although the parents tended to be highly educated. Similar levels of parent education were found in all three infant age groups (see Appendix A).

Families were recruited by obtaining infants' dates of birth and families' contact information from a regional health and social services board of the Quebec government via the intermediary of the provincial access to information commission. Parents were sent a letter describing the experiment and inviting them to participate (see Appendix B). They were then contacted by telephone and appointments were arranged if they expressed an interest in participating with their child. Parents who participated in the experiment received a certificate in the name of their child, recognizing the child's contribution to science, and a summary of the experiment results for their child's age group.

Apparatus

During testing, the infant and a parent sat within a small area (approximately 2.0 m by 3.0 m) surrounded on 3 sides by a black wooden partition. The infant sat in a child seat attached to a table and facing the middle panel of the partition. The parent sat directly behind the infant. At a distance of 1.07 m in front of the infant was a colour Apple Multiple Scan 720 Display computer monitor (40.6 cm on the diagonal) on which events were presented. Behind the computer monitor, outside the partition, were a Power Macintosh G3 computer, a Sony Trinitron Colour Video monitor (19.7 cm on the diagonal), and a Sony EVO-120 video camera. The camera was connected to the Sony monitor. The camera lens was focused on the infant's face through a hole in the partition 20 cm above the Apple monitor. The experimenter pressed keys on the computer keyboard to control the presentation of events to the infant and to record when infants looked at the events. The experimenter monitored the infant's gaze using the Sony monitor. The parent and infant could not see the experimenter during the experiment.

Stimuli

The experimental stimuli were QuickTime movies of events featuring an animal or a vehicle jumping over a wall, or an animal or a vehicle hitting a wall and rebounding. Events were presented at 640 x 480 pixel resolution. Each event contained a light blue background, a brown floor (3.1 cm tall), and a dark blue wall (9.4 cm tall, 4.0 cm wide) located a distance of 2/3 of screen width from the left edge of the screen. In each event, a familiar animal or vehicle moved across the computer screen. The forms of the animals and vehicles were static; that is, neither the animals' legs, nor the vehicles' wheels moved. See Table 1 for the animal and vehicle dimensions. The animal or vehicle emerged on the left side of the screen and moved across the screen until it neared the wall. It either jumped over the wall and departed from the screen on the right side, or hit the wall and moved backwards until it departed from the screen on the left side. The event lasted 7.0 s. Each movie consisted of four repetitions of a particular event, which were separated by a green curtain that lowered from the top of the screen in 0.5 s and then rose in 0.5 s. Thus, in total each movie lasted 31.0 s. To create these movies, photographs of animals and vehicles were obtained from books (Allégiatière, Lepine, Ridley, Rudkin, & Gillah, 1992, car: p. 45; Kerrod, 1990, horse: p. 24; Richards, 1995, cat: p. 112; Sayer, 1985, dog: p. 130) and the Internet (truck, bus). These photographs were scanned and then edited using the Adobe Photoshop 2.0 computer software. The Macromedia Director 6.5 computer software was used to create the QuickTime movies, which were played at 20 frames/second.

In the control event, the background and floor were as above, but no wall was present. In this event, the character was a red oval shape with yellow oval wing-like appendages and with a light green O-shaped ring near the top of the oval. This character was the same as one used by Rakison and Poulin-Dubois (2002) except that the appendages did not move. The character was drawn using Macromedia Director 5.0 and animated using Macromedia Director 6.5. It measured 6.1 cm tall and 9.0 cm wide,

Table 1

Dimensions of Animal and Vehicle Characters in Experiment 1 Events

	Size	
Characters	Height	Length
Animals[a]		
Cat	3.5	6.2
Dog	4.6	6.7
Horse	4.6	5.7
Vehicles		
Bus	2.7	8.0
Car	3.1	8.1
Truck	2.6	8.1

Note. Each character's dimensions are measured in centimetres.

[a] Each animal's height is measured from the highest point on the body or the ears to the ground. Each animal's length is measured from the tip of the nose to the rear-most edge of the animal's haunch. The animal's tail was not included.

including appendages. The character emerged on the left side of the screen and moved across the screen until it exited on the right side. The length and other features of presentation were identical to those of the experimental events described above.

An additional QuickTime movie (the *attention-getter*) was used to reorient the infant's gaze to the computer monitor prior to the beginning of the next trial. In this movie, a green circle expanded and contracted and the sound of a bell (ding) repeated once per second. The circle was drawn and animated using Macromedia Director.

Procedure

Prior to beginning the experiment, the parent and infant met with the experimenter in a waiting room for approximately 15 minutes. During this time, the experimenter explained the testing procedure, the parent completed the consent and participant information forms, and the experimenter played with the infant to accustom the infant to the new environment. Parents were asked to neither speak to their infants, nor point during the testing session. They were told that they could smile if the infants turned toward them. See Appendix C for the parent instructions, consent form, and participant information form.

The testing session began when the experimenter activated the attention-getter to draw the infant's gaze to the computer screen. As soon as the infant looked at the screen, the experimenter pressed a key to stop the attention-getter and begin the presentation of the first movie. The experimenter immediately pressed another key to record the infant's looking at the screen. When the infant looked away from the screen the experimenter stopped pressing this second key. If the infant looked back at the screen, the experimenter pressed the second key again. A given movie was presented for 31.0 s or until the infant looked away from the screen continuously for 1.0 s and had at least one continuous look of 0.5 s at the screen. One movie was presented per trial. After the trial ended, the attention-getter was presented to re-orient the infant's gaze to the screen and the next trial was begun as soon as the infant looked at the screen.

An infant-controlled habituation procedure was used. The testing session began with the presentation of the control event. This was followed by the habituation phase. In this phase, infants saw two events in which an animal or a vehicle followed a category-appropriate trajectory vis-à-vis the wall. In one event, a dog jumped over the wall. In the other event, a car hit the wall and rebounded (see Figures D1 and D2). Events were presented in one of two semi-random habituation orders, consisting of 16 trials each, with the following constraints: The first four trials and the last four trials alternated between the two types of events. In the intervening eight trials, a given event was presented no more than two times in a row. Within each habituation order, the two types of events were presented on half of the trials. The two habituation orders were mirror images of each other. An infant was considered to have habituated to these events when the infant's total looking time during four consecutive trials was less than 50 % of the infant's total looking time during the first four habituation trials. The test trials were presented after the infant habituated, or after all 16 habituation trials if the infant did not habituate.

In the test phase, infants saw two types of test events: a congruent event and an incongruent event. In the congruent event, a new category exemplar followed the same trajectory as the category exemplar in the habituation phase (e.g., a cat jumped over the wall). In the incongruent event, the new category exemplar did not follow the same trajectory as the category exemplar in the habituation phase (e.g., a bus jumped over the wall; see Figures D3 and D4). Across infants, 12 test-trial pairs were used. Two infants were randomly assigned to each test-trial pair. Of these 2 infants, one saw one habituation order and the other saw the other habituation order. The test-trial pairs were designed to meet the following requirements across all pairs: (a) the incongruent event was the first test trial in half of the pairs, (b) each animal and vehicle appeared equally often in incongruent and congruent events, (c) animals and vehicles appeared equally often in the first and second test trials. In 8 of the 12 test-trial pairs, the trajectory followed by the animal or vehicle was the same in both test events. The test-trial pairs are listed in Table 2. The testing session ended with the presentation of the control event.

Coding

The final sample consisted of infants who completed the experiment, habituated, and looked for at least 3.0 s at one of the test trials, whose data were not eliminated due to technical problems, experimenter error, or parental interference during the testing session.

Reliability of on-line coding was determined by having a second person code the tapes of 25% ($n = 6$) of the infants in the final sample. The second person coded tapes with the sound turned off. For 12-month-olds, the on-line and second coder agreed on trial endings for 77 of 78 trials across infants. Correlations for individual infants ranged from .992 to 1.000. For 16-month-olds, the on-line and second coder agreed on trial endings for 76 of 77 trials across infants. Correlations for individual infants ranged from .935 to 1.000. For 20-month-olds, the on-line and second coder agreed on trial endings for 76 of 76 trials across infants. Correlations for individual infants ranged from .997 to .999.

Table 2

Congruent and Incongruent Test Events in Experiment 1 as a Function of the Characters' Motion Trajectory in the Incongruent Event

Events		Event in
Congruent	Incongruent	Test Trial 1
Jumping		
Cat Jumping	Bus Jumping	Congruent
Truck Bouncing	Bus Jumping	Congruent
Cat Jumping	Truck Jumping	Congruent
Horse Jumping	Truck Jumping	Incongruent
Bus Bouncing	Truck Jumping	Incongruent
Horse Jumping	Bus Jumping	Incongruent
Bouncing		
Truck Bouncing	Horse Bouncing	Congruent
Horse Jumping	Cat Bouncing	Congruent
Bus Bouncing	Horse Bouncing	Congruent
Cat Jumping	Horse Bouncing	Incongruent
Bus Bouncing	Cat Bouncing	Incongruent
Truck Bouncing	Cat Bouncing	Incongruent

Results

The dependent variable was infants' looking times at individual events, with the exception of infants' looking time during the habituation phase, which was analysed by computing two means: a mean of the first four trials (habituation baseline block) and a mean of the last four trials (habituation criterion block). Data were screened for normality, outliers, and homogeneity of variance. A square-root data transformation was used to normalize the data distributions and meet the assumption of homogeneity of variance (Tabachnick & Fidell, 1996). One additional outlier score was identified; this score was adjusted so that it was no longer an outlier (see Appendix E for details). All analyses were conducted using an alpha level of .05. All post-hoc analyses were conducted using a Bonferroni correction. To facilitate comprehension, the means and standard deviations of untransformed data are reported in text and square-root transformed data are reported in Appendix F.

To verify that infants' looking times decreased significantly during the habituation phase, a 3 x 2 (Age x Habituation Block) analysis of variance was conducted, with habituation block as a repeated measure. Significant main effects of habituation block, $F(1, 69) = 782.63, p < .05$, and age, $F(2, 69) = 5.79, p < .05$ were found. These results were modified by a significant interaction between habituation block and age, $F(2, 69) = 3.84, p < .05$. Post-hoc analyses confirmed that all three age groups showed a significant drop in looking times during the habituation phase. Means and standard deviations are presented in Table 3 (see Table F1 for the square-root transformed data, and Table G1 for the analysis of variance table).

Table 3

Infants' Looking Times at the Post-test Trial, Habituation Baseline Block and Habituation Criterion Block for Experiment 1 by Age

	Age (months)		
Trial	12	16	20
Habituation Baseline Block			
M	12.66^{b}	$15.58^{a,c}$	18.88^{d}
SD	6.61	6.72	6.32
Habituation Criterion Block			
M	5.36^{b}	5.79^{c}	8.00^{d}
SD	3.39	3.23	3.02
Post-test			
M	5.81	10.22^{a}	8.97
SD	3.50	5.26	7.93

Note. Values represent infants' looking times in seconds. In the analyses using square-root transformed data reported in text, cells with the same letter differ significantly, $p < .017$. Looking times at the habituation baseline block and the post-test were not compared statistically.

To assess whether infants were fatigued or uninterested at the end of the experiment relative to earlier in the testing session, infants' looking times at the habituation criterion block and the post-test were compared using a 3 x 2 (Age x Control) analysis of variance, with control as a repeated measure. Infants who were not fatigued at the end of the study would be expected to look longer at the post-test than at the habituation criterion trials, because the former event is relatively novel and the latter events have been seen repeatedly. This analysis revealed main effects of control, $F(1, 69) = 5.05, p < .05$, and age, $F(2, 69) = 3.90, p < .05$. In addition, there was a control by age interaction, $F(2, 69) = 4.40, p < .05$. Post-hoc analyses revealed that 16-month-old infants looked longer at the post-test than at the end of habituation, whereas both 12- and 20-month-old infants looked equivalent amounts of times at the post-test and the end of habituation. These patterns suggest that fatigue may have influenced 12- and 20-month-olds' looking times at the test events. Means and standard deviations are presented in Table 3 (see Table F1 for the square-root transformed data, and Table G2 for the analysis of variance table.

To test whether infants detected the violation of the association between object kind and trajectory in the test phase, a 3 x 2 x 3 (Age x Sex x Trial) analysis of variance was conducted, with trial as a repeated measure, comparing infants' looking times at the criterion habituation block, congruent test event, and incongruent test event. Significant main effects of trial, $F(2, 132) =16.44, p < .05$, and age, $F(2, 66) = 6.94, p < .05$, were obtained. A significant trial by age interaction was also obtained, $F(4, 132) = 2.54, p < .05$. Post-hoc analyses revealed the following pattern: Infants of 12 months looked equally long at the habituation criterion block, congruent event ($M = 7.26$ s, $SD = 3.88$), and incongruent event (*M* = 7.50 s, *SD* = 5.07). Infants of 16 months looked equally long at the two types of test events (congruent: *M* = 11.14 s, *SD* = 8.14; incongruent: *M* = 11.72 s, *SD* = 8.04) and longer at both types of test events than at the habituation criterion block. Infants of 20 months looked significantly longer at the incongruent event (*M* = 16.98 s, *SD* = 9.75) than the congruent event (*M* = 10.36 s, *SD* = 7.38). Furthermore, their looking time at the incongruent event was significantly longer than at the habituation criterion block, whereas their looking time at the congruent event and habituation criterion block did not differ. Means and standard errors of the means are presented in Figure 1 (see Figure F1 for the square-root transformed data and Table G3 for the analysis of variance table).

The data indicate that 20-month-olds detected the violation of the association between trajectory and object kind that occurred in the incongruent test event. To determine whether infants detected the violation for both jumping and bouncing trajectories, the sub-sample of infants in each age group who looked longer at the incongruent than the congruent event was examined. This sub-sample consisted of 12, 13 and 17 infants in the 12-, 16-, and 20-month-old age groups respectively. The proportion of each sub-sample who saw a vehicle jump in the incongruent event was compared to chance using binomial tests. Only the proportion of 16-month-olds showed a trend to differ from chance: 12-month-olds, 58 %, *p* = .77; 16-month-olds, 77 %, *p* = .09; 20-month-olds, 59 %, *p* = .63. In conjunction with the previous analyses, these results suggest that 12-month-olds detected neither type of trajectory violation; 16-month-olds were somewhat more likely to detect a violation of the association between motion trajectory and vehicles than a violation of the association between motion trajectory and

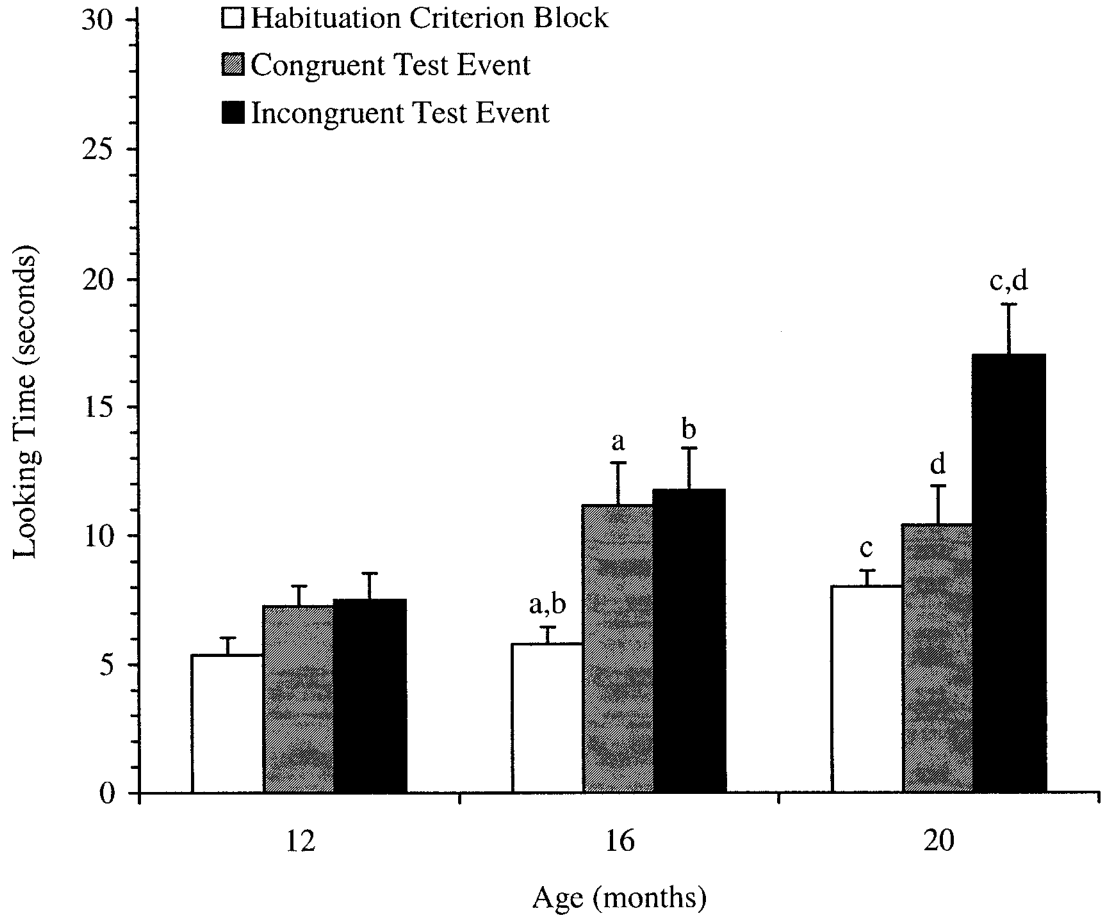

Figure 1. Mean looking times per trial (+*SE*) at the habituation criterion block, congruent, and incongruent events for infants in Experiment 1. For each age, in the analyses using square-root transformed data reported in text, bars with the same letter differ significantly, $p < .017$.

animals, suggesting that the former may emerge earlier in development; 20-month-olds, for whom the link between object kind and trajectory is well-established, detected both types of trajectory violations.

If infants have a bias to look at one kind of entity, either animals or vehicles, it could influence their looking times in the test phase and overwhelm an association between object kind and trajectory. More specifically, because half of each of the congruent and incongruent trials feature animals and half feature vehicles, a strong bias to look at one object kind would tend to produce equal look times at incongruent and congruent events. To test for an infant bias for animals or vehicles, the test phase data were analyzed for the 16 infants of each age who saw the same motion trajectory in both test events. These infants saw one animal and one vehicle in the test phase and therefore their looking time data permits a direct comparison of infants' preferences for the animals and vehicles. A 3 x 2 (Age x Object Kind) analysis of variance was conducted, with object kind as a repeated measure. Only a trend for age was found, $F(2, 45) = 2.57, p < .10$. Post-hoc analyses were conducted because the trend for age was a medium-sized effect (Cohen's f = 0.33, guideline for a medium effect is f = 0.25; Cohen, 1988), but these revealed no significant differences between looking time at test events by 12-month-olds ($M = 7.29$ s, $SD = 3.11$), 16-month-olds ($M = 10.73$ s, $SD = 6.22$), and 20-month-olds ($M = 11.91$ s, $SD = 6.21$; see Table F2 for square-root transformed data, and Table G4 for the analysis of variance table).

Discussion

In the present experiment, two possible looking time patterns were expected if infants detected the association in the habituation phase between animals and jumping (a non-linear trajectory), and between vehicles and bouncing (a linear trajectory) and generalized this association to new category exemplars in the test phase. If infants overlooked the superficial novelty of the new animals and vehicles in the test phase and reacted based on conceptual properties, they should have looked longer at the incongruent test event than at the congruent test event, longer at the incongruent test event than at the habituation criterion block, and equally long at the congruent test event and the habituation criterion block. If infants responded to the superficial novelty of the animals and vehicles in the test phase in addition to reacting based on conceptual properties, they might have dishabituated to the congruent test event and shown the above pattern in all other respects. Thus, the former pattern indicates a more robust conceptual understanding.

The results of Experiment 1 indicate that as a group 20-month-old infants, but not younger infants, detected the violation of the association between object kind and trajectory in the incongruent test event, as indicated by their longer looking times at the incongruent event than at the congruent event. Further evidence for the conclusion that 20-month-olds associated trajectory and object kind is provided by their dishabituation pattern: they dishabituated to the incongruent event and did not dishabituate to the congruent event. That is, they reacted to the novel category exemplar only when it did not follow the trajectory of the category exemplar in the habituation phase. The overall pattern is consistent with the more advanced level of knowledge described above. Infants of 20 months did not dishabituate to the post-test event, however, which suggests that they were fatigued by the time the test events were presented. Fatigue could have reduced infants' looking times at the two test events. If fatigue did reduce 20-month-olds' looking time at the test events, this would have two implications for the data. First, it would indicate that infants' ability to detect the violation of association in the incongruent event is robust, because they dishabituated to the incongruent event despite deflation of incongruent-event looking time due to fatigue. Second, infants' failure to dishabituate to the congruent test event may be partially due to fatigue. That is, if this experiment were repeated with a group of 20-month-old infants who were not fatigued, it is possible that infants' looking time at the congruent event would be significantly higher than their looking time at the habituation criterion block. Consequently, their looking time pattern would resemble the second pattern indicating less advanced knowledge of the association between trajectory and object kind.

There are three possible interpretations of 20-month-olds' looking pattern at the habituation criterion block, congruent test event, and incongruent test event in the present experiment. One interpretation is that 20-month-old infants simply *learned* the association between object kind and trajectory during the habituation phase and detected a change in this association in the incongruent event. According to this interpretation, the results of this experiment indicate that the ability to learn an association between object kind and motion trajectory emerges between 16 and 20 months. A second interpretation is that 20-month-olds looked longer at the incongruent test event than at the congruent test event because they knew a priori that the motion trajectory in the incongruent event was category inappropriate. That is, the 20-month-olds may have had pre-existing conceptual knowledge about the trajectories of animals and vehicles. Finally, it could be that infants' behaviour reflects a combination of the two processes. That is, exposure to the habituation phase may have triggered category knowledge that infants are not yet able to apply in daily life.

Although it is not possible to determine the source of the knowledge in the present experiment, it is important to remember that in the habituation phase infants saw only one exemplar from each of the categories of animals and vehicles. That is, infants were required to generalize from an individual dog to another mammal and from an individual car to another vehicle. In so doing, they also had to focus on the relationship between category and trajectory, despite the novelty of the mammals and vehicles in the test phase. In this sense, the present experiment is a stringent test of infants' understanding of the motion properties of animals and vehicles. Regardless of the source of infants' knowledge, 20-month-olds demonstrated understanding of an association between one linear trajectory and animals and one non-linear trajectory and vehicles.

In contrast to 20-month-olds, 16-month-olds dishabituated to both types of test events, indicating that they reacted to the novelty of the new animals and vehicles. As a group, their looking times at the test events did not differ, indicating that they did not associate object kind and trajectory. In the sub-sample of 16-month-olds who did look longer at the incongruent event than at the congruent event, infants were more likely to have seen a vehicle jumping as the incongruent test event. This suggests that the ability to associate a trajectory with inanimate objects may emerge earlier than for animate beings. This would be consistent with the fact that movement patterns of inanimate objects are less flexible than those of animate beings. For example, if a person approaches an obstacle, he or she may avoid the obstacle or, if not paying attention, may bump into it. If a chair is pushed toward an obstacle, however, the chair cannot avoid the obstacle and will always bump into it (assuming the push is forceful enough and the chair doesn't fall over before reaching the obstacle). The conclusion that infants' ability to associate trajectories with inanimate objects may emerge earlier than the ability to associate trajectories with animate beings should be considered preliminary given that the result for 16-month-olds was a trend.

At 12 months, infants' looking times at the incongruent, congruent, and habituation criterion block did not differ, suggesting that they treated these two events as equivalent. Their post-test data suggest that infants of this age were tired and this may have contributed to their extremely low looking times at the test events. Given that infants 4 months older and who were not fatigued did not clearly associate trajectory and object kind, however, it is unlikely that 12-month-olds' inability to associate object kind and trajectory was due solely to fatigue. These young infants may have been attending to only one element of the events, either trajectory or object kind, with the former being more likely given the perceptual salience of trajectory and the common motion trajectory in all events as the character approached the wall.

Evidence of an ability to associate object kind and trajectory was obtained at a later age than hypothesized. One possible explanation is that the events used were impoverished in that the forms of the animals and vehicles were static: the legs and heads of the animals did not move and the wheels of the vehicles did not roll. Perhaps only 20-month-olds reacted to these images as representing real animals and vehicles. In addition, the animate nature of the jumping trajectory was impoverished in the present experiment. Specifically, the animals' and vehicles' bodies were parallel with the floor throughout the jump, rather than changing orientation during the jump. Therefore, in Experiment 2 I enriched the events by adding moving parts to the animals and vehicles and enhancing the animate nature of the jumping trajectory.

Experiment 2

In Experiment 2, I added two additional cues to enhance the ecological validity of the events used in Experiment 1. First, I increased the realism of the jumping trajectory. Specifically, at the point of take-off, the front end of the vehicle or animal left the ground first. As the animal or vehicle rose, the body was at an angle relative to the floor and travelled a short distance horizontally. As the vehicle or animal passed over the wall, the body tilted until it was first parallel with the floor and then tilted until the front end was angled toward the floor as the animal or vehicle descended. Second, I added movement to the legs and heads of the animals and to the wheels of the vehicles. For the animals, biomechanical motion was added so that they walked across the screen. In the jumping animal event, when an animal approached the wall, it looked up, crouched, and then jumped over the wall. For the vehicles, the wheels of the vehicles were marked with lines to give the impression that the wheels rolled as a vehicle moved across the screen.

I tested 16-month-old infants using these modified events. In Experiment 1, the overall pattern indicated that infants of this age did not associate motion trajectory with object kind. If the lack of moving parts and somewhat anomalous jumping trajectory interfered with the performance of 16-month-olds in Experiment 1, then these more realistic events should permit 16-month-olds to associate trajectory with object kind.

Method

Participants

A total of 38 full-term infants (21 boys, 17 girls; $M = 16.33$ months, $SD = 0.19$)

participated in this study. The languages spoken in the infants' homes included English, French, or both English and French. The infants had no vision or hearing impairments, based on parent reports. Of these infants, 14 were excluded from the analysis due to the habituation criterion not being met (5 boys, 2 girls), low looking times at the test trials (1 girl), fussiness (1 boy, 2 girls), experimenter error (1 boy, 1 girl), or parental interference (1 girl). The final sample consisted of 24 infants (14 boys, 10 girls; mean age = 16.30 months; *SD* = 0.18). As in Experiment 1, parents' highest level of education indicates that families represented a range of socio-economic backgrounds; most parents were highly educated (see Appendix H).

The method of recruitment was the same as for Experiment 1.

Apparatus

The apparatus was the same as for Experiment 1.

Stimuli

The experimental stimuli were QuickTime movies that were identical to those used in Experiment 1, except where indicated.

In the animal events, the animals walked instead of sliding across the screen as in Experiment 1. Specifically, the legs moved and the body of the animal bobbed up and down. In the events in which the animal jumped over the wall, the animal walked up to the wall, looked up at the top of the wall, crouched with its front legs in the air, and leapt. The location at which the animal leapt was slightly further away from the wall than in Experiment 1. The animal jumping events were created using seven images: four images for the walking motion and three images for the jumping sequence. The images for the jumping sequence were as follows: one for the look up, one for the crouch, and one for the jumping position over the wall. Twenty-five rotations of the jumping position were used to create a smooth jumping motion. After the animal jumped, it landed front legs first. In the events in which the animal bounced, the four walking images were used and were played in reverse as the animal moved backward after hitting the wall.

In the vehicle events, the wheels appeared to roll, instead of sliding across the screen as in Experiment 1. The rolling motion was created using four images. In each image, a line was drawn on each wheel of the vehicle. The positions of the lines were rotated one-quarter turn in each image, which created the impression that the wheels rolled. The jumping and bouncing vehicle events were created using the same or analogous sequence of images as for the animals, except for the image in the jumping event in which an animal looked up at the wall, which was physically impossible for a vehicle. Instead, when the vehicle jumped, it rolled up to the wall, the front end of the vehicle tilted up for one frame (analogous to the animal crouch), and then the front end tilted further up for one frame as the vehicle rose off the ground (analogous to the animal leap).

The Adobe Photoshop 5.5 computer software was used to create multiple images of each animal and vehicle, manipulating the animals' legs and heads, the vehicles' wheels, and the rotations of the bodies of the animals and vehicles to create the events described above. See Table 4 for the animal and vehicle dimensions and Appendix I for a depiction of the two habituation events and sample incongruent animal and vehicle events.

The control event was identical to the one used in Experiment 1, except that the appendages moved vertically along the body.

Table 4

Dimensions of Animal and Vehicle Characters in Experiment 2 Events

	Size	
Characters	Height	Length
Animals[a]		
Cat	3.5	6.2
Dog	4.6	6.7
Horse	4.6	5.7
Vehicles		
Bus	2.4	7.3
Car	3.1	8.1
Truck	2.6	7.8

Note. Each character's dimensions are measured in centimetres.

[a] Each animal's height is measured from the highest point on the body or the ears to the ground. Each animal's length is measured from the tip of the nose to the rear-most edge of the animal's haunch. The animal's tail was not included.

Procedure

The procedure was the same as for Experiment 1, with the exception of the test-trial pairs. Across infants, eight test-trial pairs were used; 3 infants were randomly assigned to each test-trial pair. Of the 3 infants who saw a test-trial pair, 2 saw one habituation order and 1 saw the other habituation order. Within a pair, one event was an incongruent event and one event was a congruent event. In addition, within a pair the two test events featured the same motion trajectory. Across all test-trial pairs the following requirements were met: (a) half the pairs featured characters jumping over the wall and half featured characters bouncing into the wall, (b) the incongruent event was the first test trial in half of the pairs, and (c) the combination of a given animal or vehicle with a given motion trajectory appears once in the first test trial and once in the second test trial. The test-trial pairs are listed in Table 5.

Coding

The criteria for inclusion in the final sample were the same as for Experiment 1. Reliability of on-line coding was determined by having a second person code 25% of the tapes from the final sample ($n = 6$). The on-line and second coder agreed on trial endings for 74 of 75 trials. Correlations for individual infants ranged from .989 to 1.000.

Results

As in Experiment 1, the dependent variable was infants' looking times at individual events, with the exception of looking times at habituation events. Looking times at habituation events were measured by calculating two mean looking times for each infant: a mean of the four trials in the habituation baseline block and a mean of the four trials in the habituation criterion block. Data were screened for normality,

Table 5

Congruent and Incongruent Test Events in Experiment 2 as a Function of the Characters' Motion Trajectory

Events		Event in
Congruent	Incongruent	Test Trial 1
	Jumping	
Cat Jumping	Bus Jumping	Congruent
Horse Jumping	Truck Jumping	Congruent
Cat Jumping	Truck Jumping	Incongruent
Horse Jumping	Bus Jumping	Incongruent
	Bouncing	
Bus Bouncing	Cat Bouncing	Congruent
Truck Bouncing	Horse Bouncing	Congruent
Bus Bouncing	Horse Bouncing	Incongruent
Truck Bouncing	Cat Bouncing	Incongruent

homogeneity of variance, and outliers. One outlier was identified; this score was adjusted so that it was not an outlier (see Appendix E for details). Analyses were conducted using an alpha level of .05. A Bonferroni correction was used for post-hoc analyses.

To determine whether infants' looking times at the events decreased during the habituation phase, infants' mean looking times at the baseline and criterion habituation blocks were compared. Infants' looking times dropped significantly between baseline ($M = 18.81$ s, $SD = 7.85$) and criterion ($M = 7.10$ s, $SD = 3.00$), $t(23) = 10.84, p < .05$.

Whether infants were fatigued or uninterested at the end of the experiment relative to earlier was assessed by comparing infants' mean looking times at the habituation criterion block and the post-test event. Infants looked longer at the post-test ($M = 11.36$ s, $SD = 8.47$) than at the habituation criterion block, $t(23) = 2.48, p < .05$. This pattern of results indicates that infants were still interested in the task at the end of the experiment and, therefore, that fatigue did not influence their looking times at the test events.

To assess whether infants detected the violation of the association between object kind and trajectory in the test phase, a 2 x 3 (Sex x Trial) analysis of variance was conducted, where trial was a repeated measure consisting of looking time at the habituation criterion block, congruent test event, and incongruent test event. A significant main effect of trial was found, $F(2, 44) = 5.02, p < .05$ (see Table J1 for the analysis of variance table). Post-hoc analyses revealed that infants looked significantly longer at both the congruent ($M = 12.97$ s, $SD = 10.16$) and the incongruent ($M = 10.72$ s, $SD = 8.39$) test events than at the end of the habituation phase, but their looking times at the two types of test events did not differ. These data indicate that infants detected the presence of novel animals and vehicles during the test phase, but did not react to the central difference between the two test events: the maintenance of the association between motion trajectory and object kind in the congruent event and the breaking of this association in the incongruent event.

It is possible that infants detected only one of the two types of violations of association that were tested in the incongruent events. This possibility was assessed using a 2 x 3 (Motion x Trial) repeated-measures analysis of variance. This analysis was used to compare the reactions to the incongruent event of infants who saw jumping trajectories in the test phase and infants who saw bouncing trajectories in the test phase. A significant main effect of trial was found, $F(2, 44) = 5.07, p < .05$. In addition, there was a trend for an interaction between motion and trial, $F(2, 44) = 2.83, p < .10$ (see Table J2 for the analysis of variance table). The effect size for this interaction was a marginally medium-sized effect (Cohen's $f = 0.24$; guideline for a medium effect is $f = 0.25$; Cohen, 1988). Therefore, this trend was examined using post-hoc analyses. As is depicted in Figure 2, infants who saw jumping events in the test phase looked significantly longer at the incongruent event ($M = 15.21$ s, $SD = 10.09$) than at the habituation criterion block ($M = 8.02$ s, $SD = 3.22$); the other comparisons were not significant (jumping test group: congruent event $M = 13.07$ s, $SD = 10.55$; bouncing test group: habituation criterion block $M = 6.18$ s, $SD = 2.43$, congruent event $M = 12.87$ s, $SD = 10.95$, incongruent event $M = 6.62$ s, $SD = 4.49$).

To determine whether a bias to look at animals or vehicles might have dominated infants' looking behaviour during the test phase, infants' mean looking times at animals and vehicles in test events were compared. This analysis revealed a marginally significant

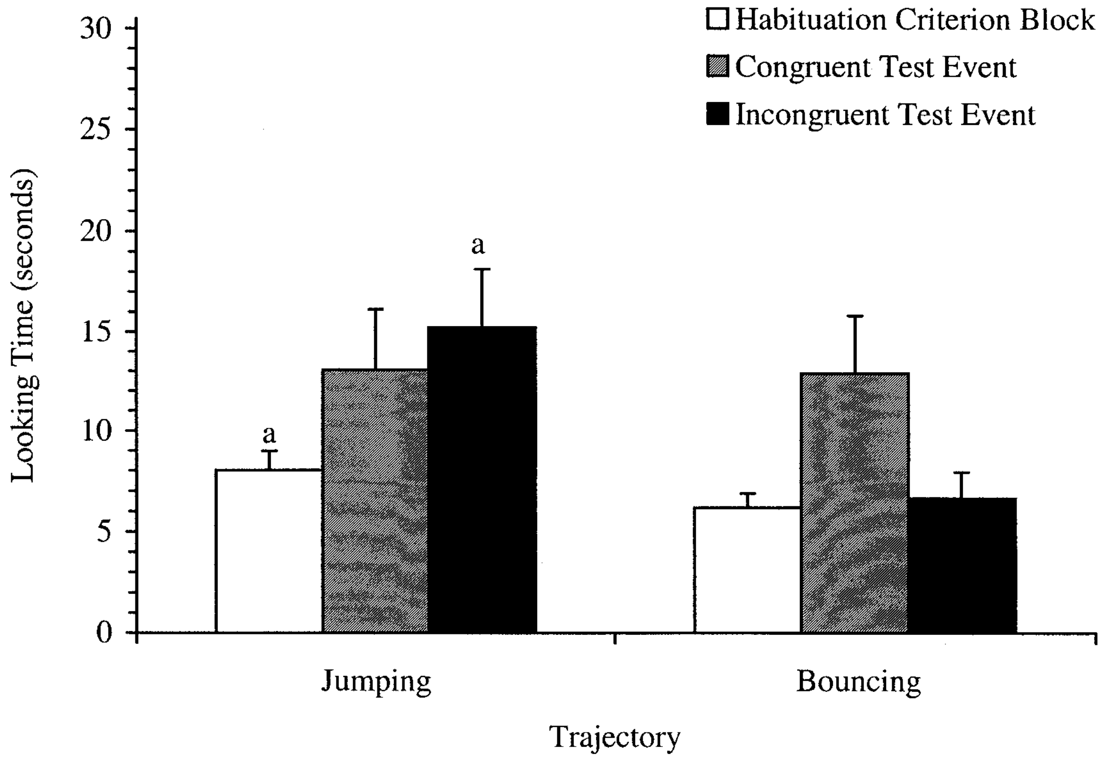

Figure 2. Mean looking times per trial (+*SE*) at the habituation criterion block, congruent, and incongruent events separately by trajectory for 16-month-olds in Experiment 2. For each trajectory, bars labelled with the same letter differ significantly, $p < .017$.

difference: infants looked longer at the vehicles (*M* = 14.04 s, *SD* = 10.00) than at the animals (*M* = 9.84 s, *SD* = 8.59), *t*(23) = 2.07, *p* = .05.

Discussion

In this experiment, infants' ability to associate motion trajectories and object kinds was tested by modifying the design and stimuli used in Experiment 1. The design was modified in that all infants saw the same motion trajectory in the two test events, whereas in Experiment 1 one third of infants saw different motion trajectories in the two test events. Stimuli were modified by: (a) adding biomechanical properties to the animals' movement, (b) adding a rolling motion to the vehicles' wheels, and (c) increasing the animate nature of the jumping trajectory by altering the characters' body orientation during the jump.

Despite the increased ecological validity of the stimuli, the pattern of looking times was markedly similar to that of 16-month-olds in Experiment 1. Infants looked equally long at the congruent and incongruent test events and longer at both test events than at the end of habituation phase. This overall pattern of looking times indicates that infants detected the new animals and vehicles in the test phase, but did not detect the violation of the habituation-phase association between object kind and motion trajectory in the incongruent test event. There was some evidence that infants detected the violation of the association when the incongruent event featured a jumping vehicle. Specifically, infants who saw a jumping trajectory in the two test events looked longer at the incongruent event in which a vehicle jumped over the wall than at the end of the habituation phase, suggesting that infants detected the violation of trajectory for vehicles. This pattern is consistent with the results of Experiment 1 in which 16-month-old infants who looked longer at the incongruent than the congruent test event were more likely to have seen an incongruent event in which a vehicle jumped. This provides preliminary evidence that infants as young as 16 months may associate trajectories with vehicles.

The interpretation that the ability to associate trajectory with vehicles is present at 16 months is weakened by the fact that infants did not look longer at the vehicle-jumping incongruent test event than at the animal-jumping congruent test event. If 16-month-olds do understand that bouncing is associated with vehicles, they should have detected the trajectory violation of a jumping vehicle and looked longer at this event than at the animal-jumping congruent test event. In addition, infants showed a marginally significant tendency to look longer at vehicles than animals, regardless of motion trajectory. It could be argued that infants' bias for vehicles explains the longer looking times at the incongruent jumping events than at the habituation criterion block. If infants' looking times in the test phase were dominated by a vehicle bias, however, one would also expect other patterns in the data. First, infants who saw jumping in the test trials should look longer at the incongruent event, a jumping vehicle, than at the congruent event, a jumping animal. Second, infants who saw bouncing in the test trials should: (a) look longer at the congruent event, a bouncing vehicle, than at the incongruent event, a bouncing animal; and (b) look longer at the congruent event, a bouncing vehicle, than at the habituation criterion block. Although inspection of the data suggests that the means are consistent with the second and third looking-time patterns, the differences between means were not statistically significant. It is not possible to rule out definitively a role for vehicle bias in infants' dishabituation to the jumping vehicle. The consistency between these data and the data from Experiment 1 in which there was no vehicle bias, however, warrants a preliminary conclusion that the ability to associate vehicles with trajectories emerges at a younger age than the ability to associate animals with trajectories. In summary, the data from Experiment 2 provide no evidence that the unexpectedly late emergence of trajectory association with animals and vehicles obtained in Experiment 1 was caused by the somewhat unrealistic stimuli interfering with 16-month-olds treating the images of animals and vehicles as representing real animals and vehicles.

The finding that infants did not associate motion trajectory and object kind until 20 months of age differs from Poulin-Dubois and Vyncke (2002), who found understanding of this association at 14 months. In interpreting this difference, it should be borne in mind that the response rate in Poulin-Dubois and Vyncke's study was somewhat low, particularly for 14-month-olds. In addition, several methodological differences between the two experiments may have contributed to the age difference. Poulin-Dubois and Vyncke used three-dimensional replicas, whereas the present experiments used two-dimensional animated events. Perhaps the former were better at tapping into infants' knowledge, either because of realism (but note that increased realism in the present experiments did not improve 16-month-olds' performance) or because of the physical interaction between the experimenter and the replicas or the physical interaction between the infant and the replicas. It is problematic to test knowledge of motion using three-dimensional replicas, however, precisely because the infant and experimenter must physically manipulate (i.e., move) the replicas. It could be argued that this physical manipulation of the replicas introduces a confound into the experiment, particularly when testing infants' knowledge of the motion of animate beings, because such motion should be under the control of the animate being itself. Second, the present experiments and that of Poulin-Dubois and Vyncke (2002) differ in the motion trajectories tested. The only overlap between the two research projects was the motion trajectory of jumping over a block. It is noteworthy that for this motion trajectory Poulin-Dubois and Vyncke found that it was only at 18 months that infants correctly associated object kind and motion trajectory. Third, Poulin-Dubois and Vyncke incorporated a sound into the motion events, which may have helped infants focus on the association between object kind and motion.

Considered together, the results of the present two experiments indicate that the ability to associate different lines of trajectory with object kind emerges between 16 and 20 months of age, suggesting that infants' concepts of animals and vehicles do not have motion trajectory as a component until 20 months. Given that a number of motion cues have been proposed to underlie infants' animate-inanimate distinction, an important research question is whether infants in the second year of life associate other motion cues with animals and vehicles, in addition to line of trajectory. This issue is addressed in the next chapter.

CHAPTER 3: INFANTS' KNOWLEDGE OF THE ASSOCIATION BETWEEN OBJECT KIND AND TYPE OF MOTION ONSET

Experiment 3

I examined infants' ability to associate object kinds with another motion cue, the way in which something stationary begins to move, in Experiment 3. Specifically, I tested infants' ability to associate self-initiated motion onset with animals and externally caused motion onset with vehicles. As in Experiment 2, the characters had moving parts in order to maximize the ecological validity of the events. The vehicle exemplars were different from the ones used in Experiment 2 in that the exemplars were clearly externally propelled. This change was made because the vehicle exemplars used in the previous experiments had combustion engines. The only evidence of external propulsion for this type of vehicle is turning a key and pushing on the gas pedal, actions that lack both salience and a clear visible connection to the motion onset. In Experiment 3, the vehicle exemplars were a stroller and a tricycle, vehicles that are moved in an observable manner by an external force.

The experimental design was similar to Experiment 2 in that a given infant saw one animal and one vehicle in the habituation phase and the same type of motion cue in both test events. The experimental design was improved in two respects from the design used in Experiments 1 and 2. First, in the habituation phase of the previous experiments infants saw two events in one of two presentation orders. In the habituation phase of Experiment 3, infants also saw two events, but a unique habituation order was created for each infant and each of these orders met the criteria laid out in the procedure section of Experiment 1. Second, in Experiment 2, all infants saw the same animal (a dog) and the same vehicle (a car) in the habituation phase and one of two possible animals and one of two possible vehicles in the test phase (a total of eight different test-trial pairs were used). In Experiment 3, the stimuli used in the habituation and test phase were counterbalanced. To achieve this without having a prohibitively large number of event pairs, two animals and two vehicles were used and a given animal was always paired with a given vehicle. Specifically, half of the infants saw one animal-vehicle pair in the habituation phase and the other animal-vehicle pair in the test phase. The other half of the infants saw the same pairings of animal and vehicle, but the phase in which they saw the pairs was changed. The purpose of this design modification was to assess the robustness and generalizability of the results to different exemplars.

Only 16-month-olds were tested in the present experiment. I chose this age because they were the youngest age at which infants demonstrated partial knowledge of the association between line of trajectory and object kind in the previous experiments. I expected that infants at this age might associate type of motion onset with object kind for several reasons. First, theoreticians have emphasized the importance of type of motion onset to the distinction between animate beings and inanimate objects (e.g., Mandler, 1992a; Poulin-Dubois, 1999; Rakison & Poulin-Dubois, 2001). Second, although there is a lack of evidence that infants discriminate between self-initiated and externally caused motion per se, there is preliminary evidence that infants associate type of motion onset with humans and inanimate objects as young as 7 months of age (Woodward et al., 1993, as cited in Spelke et al., 1995) (but see Leslie, 1984a), with confirming evidence found for infants at 9, 12 (Poulin-Dubois et al., 1996), and 24 months (Golinkoff & Harding, 1980, as cited in Golinkoff et al., 1984), depending on the methodology and stimuli used.

Method

Participants

A total of 39 full-term infants (16 boys, 23 girls; *M* = 16.26 months, *SD* = 0.24) participated in this study. The languages spoken in the infants' homes included English, French, or both English and French. The infants had no vision or hearing impairments, based on parent reports. Of these infants, 15 were excluded from the analysis due to the habituation criterion not being met (2 boys, 2 girls), fussiness (3 boy, 6 girls), or experimenter error (2 girls). The final sample consisted of 24 infants (11 boys, 13 girls; mean age = 16.33 months; *SD* = 0.21). As measured by parents' highest level of education, families represented a range of socio-economic backgrounds, although the parents tended to be highly educated (see Appendix K).

The method of recruitment was the same as for Experiment 1.

Apparatus

The apparatus was the same as for Experiment 1.

Stimuli

The stimuli were QuickTime movies of events featuring an animal or vehicle that began to move with or without a push by a lever and then continued to move across the screen until it departed on the screen's right edge. As in Experiment 1, events were presented at 640 x 480 pixel resolution. In each event, there was a white background, a green floor (5.7 cm tall), and a black lever consisting of a handle and a rectangular tool end (3.2 cm tall, 1.8 cm wide) that emerged from the left edge of the screen. Animals walked and vehicles rolled across the screen. The dimensions of the animals and vehicles are presented in Table 6.

Table 6

Dimensions of Animal and Vehicle Characters in Experiment 3 Events

	Size	
Characters	Height	Length
Animals[a]		
Goat	5.9	6.8
Pig	4.8	7.4
Vehicles		
Stroller	8.1	7.8
Tricycle	7.2	7.5

Note. Each character's dimensions are measured in centimetres.

[a] Each animal's height is measured from the highest point on the body or the ears/horns to the ground. Each animal's length is measured from the tip of the nose to the rear-most edge of the animal's haunch. The animal's tail was not included.

Prior to each event, a curtain rose from the bottom to the top of the screen in 0.5 s. As the curtain rose, the animal or vehicle was revealed stationary on the left side of the screen, with its front end oriented toward the right side of the screen. The event began as soon as the curtain reached the top of the screen. In the externally caused event, a lever immediately emerged from the left edge of the screen and contacted the animal or vehicle after 1.25 s. The lever and the character maintained contact for 0.15 s while they both moved to the right. Then, the lever stopped moving and the character continued moving across the screen until it departed on the right hand side. To enhance the impression that the lever caused the animal or vehicle to move, neither the animals' legs nor vehicles' wheels moved while the lever was in contact with the animal or vehicle. In the self-initiated motion event, the sequence was identical except that the lever moved for 0.75 s and stopped approximately 2.3 cm to the left of where the lever contacted the character in the externally caused event. After a pause of 0.5 s, the character began to move. The duration of the pause was equal to the additional amount of time it took the lever to contact the character in the externally caused motion event. As in previous experiments, the duration of each event was 7.0 s and each movie consisted of four repetitions of a particular event. Each movie began with a green curtain rising from the bottom to the top of the screen for 0.5 s; in between events in a movie this curtain lowered for 0.5 s and rose for 0.5 s; after the final event in a movie the curtain lowered for 0.5 s. In total, each movie lasted 32.0 s.

As in Experiment 2, the legs on the animals moved and the animals bobbed up and down as they walked. The walking motion was created using four images in which the position of the limbs was modified. As in Experiment 2, the wheels of the vehicles appeared to roll as the vehicle moved across the screen. The rolling motion was created using four images in which a line was drawn on each wheel and the positions of the lines were rotated in each image. To create the movies, colour drawings of the animals and vehicles were obtained from a children's picture book (*L'imagier du père castor*, 1977) and were then scanned and edited using the Adobe Photoshop 5.5 computer software, which was also used to manipulate the legs and wheels and create the multiple images of each animal and vehicle described above. The QuickTime movies were created using the Macromedia Director 6.5 computer software. Sample habituation events and sample incongruent animal and vehicle test events are presented in Appendix L.

In the control event, the background and floor were the same as in the events described above. No lever was present. In this event, the character was a blue trapezoid with green diamond wing-like appendages and with a light blue star near the bottom of the trapezoid. The character was one used in an experiment by Rakison and Poulin-Dubois (2002). It was drawn using Macromedia Director 5.0 and animated using Macromedia Director 6.5. As in Experiment 2, the appendages moved. The character measured 6.0 cm tall and 8.9 cm wide, including appendages. The character emerged on the right side of the screen and crossed the screen until it departed on the left side. The length and other features of presentation were identical to the experimental events.

Procedure

The procedure was the same as for Experiments 1 and 2, with the following exceptions. Each infant saw a unique order of events in the habituation phase. Each of these orders met the constraints outlined in Experiment 1. In half of the habituation orders the first trial featured self-initiated motion onset by an animal and in half of the habituation orders the first trial featured externally caused motion onset by a vehicle. Furthermore, infants were divided into two groups. One group saw a goat and a stroller in the habituation phase and a pig and a tricycle in the test phase. The other group saw the opposite. A total of eight test-trial pairs were used of which four were seen by each group of infants. Three infants were randomly assigned to each test-trial pair. Within each test-trial pair, one event was an incongruent event and one event was a congruent event. Also within each pair, the two test events featured the same type of motion onset. Within each group of infants and across the test-trial pairs: (a) half the test-trial pairs featured self-initiated motion onset and half featured externally caused motion onset, (b) half the test-trial pairs featured the incongruent event in the first test trial, and (c) the combination of a given animal or vehicle and a type of motion onset was featured once in the first test trial and once in the second trial. Although these criteria across and within test-trial pairs were the same as, or analogous to, those used in Experiment 2, one difference was that all the infants in a group saw the same animal and the same vehicle in the test phase. The experimental design is presented in Table 7.

Coding

The final sample consisted of infants who completed the experiment and habituated, whose data were not eliminated due to technical problems, experimenter error, or parental interference during the testing session. No infants' data had to be excluded due to technical problems or parental interference. Unlike for Experiments 1 and 2, a minimum looking time at the test events was not used as an inclusion criterion because the critical component, the motion onset, occurred very early in the events.

Table 7

Experimental Design of Experiment 3

	Habituation Events		Test Events	
Group	Animal	Vehicle	Congruent	Incongruent
1A	Self-initiated goat	Caused stroller	Caused tricycle	Caused pig
1B	Self-initiated goat	Caused stroller	Self-initiated pig	Self-initiated tricycle
2A	Self-initiated pig	Caused tricycle	Caused stroller	Caused goat
2B	Self-initiated pig	Caused tricycle	Self-initiated goat	Self-initiated stroller

Note. For each of the four pairs of test events listed, half of the infants saw the incongruent event in the first test trial and half of the infants saw the congruent event in the first test trial. Thus, there were eight test-trial pairs.

As for previous experiments, reliability of on-line coding was determined by having a second person code 25% of the final samples' tapes. The two coders agreed on trial endings for 86 of 86 trials. Correlations for individual infants ranged from 0.992 to 1.000.

Results

The dependent variable was infants' looking time at the events and was defined as in previous experiments. Data were screened for normality, homogeneity of variance, and outliers (see Appendix E for details). As in previous experiments, analyses were conducted using an alpha level of .05 and a Bonferroni correction was used for post-hoc analyses.

Infants' mean looking times at the habituation baseline block and the habituation criterion block were compared to determine whether infants' interest in the events decreased during the habituation phase. Infants looked significantly longer at events in the habituation baseline block ($M = 17.56$ s, $SD = 7.21$) than at events in the habituation criterion block ($M = 7.48$ s, $SD = 3.41$), $t(23) = 12.10$, $p < .05$.

Infants' looking times at the habituation criterion block and the post-test event were compared to determine whether infants were fatigued or uninterested at the end of the experiment. Infants' looking times at the habituation criterion block and the post-test event ($M = 9.68$ s, $SD = 7.67$) did not significantly differ, $t(23) = 1.27$, $p > .05$. This pattern suggests that infants' looking times at the test events may have been affected by fatigue.

To determine whether infants' looking times at the habituation criterion block, congruent test event, and incongruent test event were influenced by the exemplars seen in the habituation and test phases, a 2 x 3 (Group x Trial) mixed analysis of variance was conducted. Group refers to whether infants saw the goat-stroller pair in the habituation phase and the pig-tricycle pair in the test phase, or vice versa. Trial refers to the comparison between the habituation criterion block, congruent test event, and incongruent test event. Only a significant main effect of trial was found, $F(2, 44) = 4.54$, $p < .05$. Using post-hoc analyses, it was determined that infants' looking time at the congruent test event ($M = 13.75$ s, $SD = 10.78$) and incongruent test event ($M = 13.25$ s, $SD = 8.62$) did not significantly differ, although looking times at both test events were longer than at the habituation criterion block (see Table M1 for the analysis of variance table). Given that the character pair used in each phase of the experiment did not influence infants' performance, the data were collapsed across this variable in the remaining analyses.

Whether infants detected the violation of the association between motion onset and object kind in the test phase was assessed by comparing their looking time at the habituation criterion block, the congruent test event, and the incongruent test event using a 2 x 3 (Sex x Trial) analysis of variance, with trial as a repeated measure. Again, only a significant main effect of trial was found, $F(2, 44) = 4.51, p < .05$, reflecting that infants looked significantly longer at the congruent and incongruent test event than at the end of the habituation phase and that infants looked equally long at the two types of test events. Means and standard errors of the means are presented in Figure 3 (see Table M2 for the analysis of variance table).

To determine whether infants detected only one of the two violations of association between motion onset and object kind, a 2 x 3 (Motion x Trial) mixed

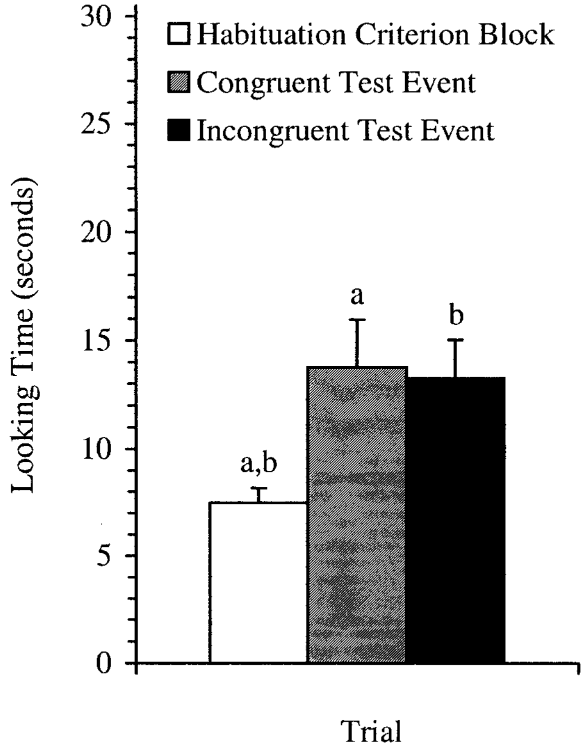

Figure 3. Mean looking times per trial (+*SE*) at the habituation criterion block, congruent, and incongruent events for 16-month-olds in Experiment 3. Bars labelled with the same letter differ significantly, $p < .017$.

analysis of variance was conducted, where motion refers to self-initiated versus externally caused motion onset. Again, only a significant effect of trial was found, $F(2, 44) = 4.45$, $p < .05$, as described above (see Table M3 for the analysis of variance table). Thus, infants detected the new characters in the test events, as indicated by the significantly longer looking times at both the congruent and incongruent test events than at the habituation criterion block. However, they detected neither the violation between self-initiated motion onset and object kind, nor the violation between externally caused motion onset and object kind, as indicated by the lack of interaction between motion and trial and the lack of difference between looking times at the congruent and incongruent test events.

If infants have a bias to look at animals or vehicles, their looking times at the test events could be dominated by this bias and consequently infants may be unable to detect the violation of association in the incongruent test event and the maintenance of association in the congruent test event. To test for a category bias, as in previous experiments, infants' looking times at animals and vehicles in the test phase were compared. Infants showed no bias to look longer at animals ($M = 13.28$ s, $SD = 9.54$) or vehicles ($M = 13.71$ s, $SD = 9.98$), $t(23) = -0.15$, $p > .05$.

Discussion

In this experiment, I assessed 16-month-old infants' ability to associate two types of motion onsets, self-initiated and caused, with two types of object kinds, animals and vehicles. The data indicate that infants did not associate object kinds and motion onsets, as indicated by the equivalence of their looking times at the test event in which the category-plus-motion-onset association was maintained (congruent event) and at the test event in which the category-plus-motion-onset association was violated (incongruent event). Infants did detect the new characters used in the test phase, as indicated by the significantly longer looking times at both types of test events than at the end of the habituation phase. Infants' looking times at the incongruent and congruent events were not influenced by the exemplars used in the two experiment phases, the type of motion onset presented in the test phase events, or the infants' sex.

Several possible explanations for infants' lack of association between motion onset and object kind may be considered. Two of these are unlikely given the data collected in the present experiment. First, if infants had a bias to look at animals or vehicles, this could explain infants' lack of association between motion onset and object kind. Infants' looking times at animals and vehicles during the test phase were similar, however, suggesting that infants' lack of association between motion onset and object kind was not caused by an object kind bias. Second, it is possible that fatigue may have influenced infants' looking times during the test phase, given that infants' looking times at the end of the habituation phase and the post-test event did not differ. Infants dishabituated to both test events, however, so it is unlikely that the inability of infants to associate type of motion onset and object kind was primarily due to fatigue. Third, it is possible that infants did not discriminate between the two types of motion onset used in this experiment. In both motion onset events, a lever emerged from the left edge of the screen. In the externally-caused motion-onset event, the lever moved until it contacted the character. When contact was made, the character began to move forward (to the right) and the lever maintained contact with it briefly. Then the lever stopped moving and the character continued moving forward. In the self-initiated motion onset event, the lever emerged and stopped before it contacted the character. After a pause, the character began to move forward. The difference of experimental interest between the two types of motion events is that in the externally-caused motion-onset event there was contact between the lever and the character whereas in the self-initiated motion-onset event there was no contact between the lever and the character. It is possible that infants did not discriminate between the contact in the externally-caused motion-onset event and the lack of contact in the self-initiated motion-onset event. This possibility was examined in the next experiment.

Experiment 4

In Experiment 4, I tested whether 16-month-old infants are able to discriminate between the externally-caused motion-onset event and the self-initiated motion-onset event in Experiment 3. This was done by testing infants' ability to discriminate between the presence and absence of contact between the lever and a particular character. Infants saw the same two characters in both phases of the experiment. In the habituation phase, infants saw a self-initiated goat and an externally caused stroller. In the test phase, infants saw either self-initiated motion onset by both the goat and the stroller or externally caused motion onset by both the goat and the stroller. Thus, each infant saw one test event that was identical in terms of both character and motion onset to one of the habituation events (same motion event) and one test event that was identical in terms of character to the other habituation event, but the type of motion onset was changed (changed motion event). If infants discriminate between the two types of motion onset, they are expected to detect a change in type of motion onset and therefore look longer at the changed motion test event than at both the same motion test event and the habituation criterion block. If infants associate each type of motion onset with each individual character in the habituation phase, infants are expected to look equally long or less long at the same motion test event than at the habituation criterion block. Thus, a pure switch design (e.g., Younger & Cohen, 1986) was used, in contrast to the modified switch design that was used in Experiments 1 to 3 in which the co-variation between motion and category, not individual, was maintained in one test event and changed in the other test event.

Method

Participants

A total of 15 full-term infants (8 boys, 7 girls; *M* = 16.31 months, *SD* = 0.17) participated in this study. The languages spoken in the infants' homes included English, French, or both English and French. The infants had no vision or hearing impairments, based on parent reports. Of these infants, 3 were excluded from the analysis due to experimenter error (1 boy, 1 girl), or parental interference (1 girl). The final sample consisted of 12 infants (7 boys, 5 girls; mean age = 16.31 months; *SD* = 0.18). As measured by parents' highest level of education, families represented a range of socio-economic backgrounds, although the parents tended to be highly educated (see Appendix N).

The method of recruitment was the same as for Experiment 1.

Stimuli and Procedure

The stimuli were the self-initiated and externally caused motion onset goat, the self-initiated and externally caused motion onset stroller, and the control event used in Experiment 3. The procedure was the same as for Experiment 3 except that all infants saw the goat and stroller in both the habituation and test phases. The experimental design is presented in Table 8. Note that the same motion test event is analogous to the congruent test event and the changed motion test event is analogous to the incongruent test event in Experiment 3.

Coding

The criteria for inclusion in the final sample were the same as for Experiment 3.

As for previous experiments, reliability of on-line coding was determined by having a second person code 25% of the final samples' tapes (*n*=3). The two coders agreed on trial endings for 44 of 45 trials. Correlations for individual infants ranged from 0.956 to 1.000.

Results

The dependent variable was the amount of time infants looked at events and was defined as in previous experiments. Data were screened for normality, homogeneity of variance, and outliers (see Appendix E for details). As in previous experiments, an alpha level of .05 was used for analyses and the Bonferroni correction was used for post-hoc analyses.

The amount of time infants looked at the habituation baseline block and the habituation criterion block were compared to determine whether infants' looking time at events declined significantly during the habituation phase. Infants looked less long at the criterion block (M = 7.77 s, SD = 3.47) than at the baseline block (M = 18.60 s, SD = 6.53), $t(11) = 11.00$, $p < .05$.

To determine whether infants were fatigued or uninterested at the end of the

Table 8

Experimental Design of Experiment 4

	Habituation Events		Test Events	
Group	Animal	Vehicle	Same motion	Changed motion
1A	Self-initiated goat	Caused stroller	Caused stroller	Caused goat
1B	Self-initiated goat	Caused stroller	Self-initiated goat	Self-initiated stroller

Note. For both pairs of test events listed, half of the infants saw the changed motion event in the first test trial and half of the infants saw the same motion event in the first test trial. Thus, there were four test-trial pairs.

experiment, the amount of time infants looked at the habituation criterion block and the post-test event were compared. Infants looked significantly longer at the post-test event ($M = 15.44$ s, $SD = 10.41$) than at events in the habituation criterion block, $t(11) = 2.62$, $p < .05$. This difference in mean looking times indicates that infants were engaged by the events at the end of the experiment and, therefore, suggests that fatigue did not influence infants' looking at the test events.

Whether infants detected the changed motion onset in one of the test events was assessed using a repeated-measures analysis of variance on trial, comparing infants' looking times at the habituation criterion block, same motion event, and changed motion event. The main effect of trial was not significant, $F(2,22) = 1.69$, $p > .05$ (see Appendix O for the analysis of variance table). Infants did not discriminate between the habituation criterion block, same motion test event ($M = 4.64$ s, $SD = 3.19$), and changed motion test event ($M = 8.62$ s, $SD = 7.91$). Due to the small sample size and the expectation that virtually all infants should detect the change in motion onset in the changed motion event, the roles of infant sex and type of motion onset were not examined.

If infants have a bias to look at the goat or the stroller, their looking times at the test events could be dominated by this preference and therefore infants may be unable to detect a change in type of motion onset. Infants' looking times at the goat and stroller in the test phase were compared to test for a bias. Infants did not show a bias to look at the goat ($M = 5.75$ s, $SD = 5.45$) or the stroller ($M = 7.52$ s, $SD = 7.07$), $t(11) = -0.61$, $p > .05$.

Discussion

In this experiment, I assessed 16-month-olds' ability to discriminate between when the lever contacted the character in the externally-caused motion-onset event and the lack of contact between the lever and character in the self-initiated motion-onset event. Infants saw one test event that was the same as one of the habituation events in terms of character and type of motion onset and one test event that was the same as the other habituation event in terms of character, but differed from it in type of motion onset. Infants' looking times at the habituation criterion block, same motion test event, and changed motion test event did not differ. This lack of difference is unlikely to be caused by either fatigue or a character bias, because infants were not fatigued at the end of the experiment and showed no looking time bias for the goat or stroller in the test phase.

Two other possible explanations for the data may be offered. First, infants may not have discriminated between the contact and lack of contact. That is, they may not have detected the physical gap between the lever and character in the self-initiated motion-onset event or the contact between the lever and character in the externally-caused motion-onset event. Second, infants may have considered the events equivalent, perhaps because there was temporal contingency between the lever's motion and the character's motion onset in both types of events. In the externally-caused motion-onset event, the lever moved until it contacted the stationary character; the lever then stopped moving and the character began to move. In the self-initiated motion-onset event, the lever stopped moving before it contacted the stationary character and there was a pause before the character began to move: The duration of this pause was the amount of time it would have taken the lever to reach the character.

Regardless of the explanation, the pattern of looking times indicates that infants were unable to associate one type of motion onset with an individual character. In this experiment, all factors except the type of motion onset were held constant. Given that infants were unable to associate one type of motion onset with an individual character, these data provide an explanation of the null results obtained in Experiment 3. Specifically, infants' inability to associate categories and types of motion onset may have been caused by infants' difficulty in differentiating the particular types of motion onset tested and not necessarily an inability to associate types of motion onset, in general, with object kinds.

CHAPTER 4: GENERAL DISCUSSION

Summary of Results

In this dissertation, I used the infant-controlled habituation paradigm to assess the ability of 12- to 20-month-old infants to associate two lines of trajectory (jumping and bouncing) and two motion onsets (self-initiated onset and externally caused onset) with mammals and vehicles. Four experiments were conducted to examine these issues. Infants saw two events in the habituation phase of each experiment. One of these events featured a mammal and the other event featured a vehicle. In each habituation event the mammal or vehicle performed a category-appropriate motion. Infants saw two events in the test phase. Each test event featured a new category exemplar in Experiments 1, 2, and 3. The habituation-phase pairing of category and motion cue was maintained in one of the test events, that is, the new category member moved in accord with its category membership. The habituation-phase pairing of category and motion cue was broken in the other test event, that is, the new category member did not move in accord with its category membership. In the test phase of Experiment 4, infants saw the same two category exemplars as during the habituation phase. The motion cue was the same for one of these exemplars and for the other exemplar it was different.

In the first two experiments, I assessed infants' ability to associate one line of trajectory, jumping, with mammals and another line of trajectory, bouncing, with vehicles. In Experiment 1, this ability was tested under stringent conditions in which the legs of the animals and the wheels of the vehicles did not move. These conditions were considered to provide a stringent test because line of trajectory was manipulated while controlling for the typical motions of animals' and vehicles' parts. The motions of animals' and vehicles' parts were eliminated to prevent infants from associating moving parts and line of trajectory. Infants aged 12, 16, and 20 months participated in this experiment. Only 20-month-olds were found to associate mammals with jumping and vehicles with bouncing. When the data were collapsed across trajectories, there was no evidence that the present sample of 16-month-olds formed these associations. A sub-sample of 16-month-olds did detect the trajectory-kind violation in the incongruent event. These infants were somewhat more likely to have seen a vehicle than an animal in the incongruent event. This result was interpreted as preliminary evidence that expectations about vehicles' trajectories develop at a younger age than expectations about animals' trajectories. At 12 months of age, infants did not associate trajectory and object kind for either the animals or the vehicles.

In Experiment 2, the ecological validity of the events used in Experiment 1 was enhanced in two ways. First, motion was added to the functional parts of the animals (legs) and vehicles (wheels) to create a walking motion for animals and a rolling motion for vehicles. Second, the animate features of the jumping trajectory were increased. For example, while a character jumped its body orientation body changed in a realistic manner. One group of infants aged 16 months participated in this experiment. When the data were collapsed across the two types of trajectories, there was no evidence that 16-month-olds associated trajectory and object kind. When the data were considered separately by trajectory there was weak evidence that infants detected a violation of trajectory for vehicles. Thus, despite the enhanced ecological validity of events in Experiment 2 relative to Experiment 1, 16-month-olds performed similarly in the two experiments. The consistency of 16-month-olds' performance suggests that 16-month-olds' inability to associate trajectory and object kind in Experiment 1 was not caused by a lack of realism in the displays. Furthermore, the consistency of 16-month-olds' performance in the two experiments suggests that infants' association between object kind and motion trajectory in Experiment 1 was not based merely on infants associating object parts with motion trajectories (e.g., legs with jumping). If this were the case, adding motion to the object parts in Experiment 2 would have improved infants' performance because moving the object parts increases their saliency. The evidence for this interpretation is strongest for 16-month-olds because this age group was tested under both conditions. This is also likely to be a valid interpretation of 20-month-olds' data because a part-trajectory association is a simple association and it is unlikely that the performance of older infants (20-month-olds) is based on a simple association if the performance of younger infants (16-month-olds) is not based on this simple association. Data collected recently in a follow-up experiment (Demke, 2002; Demke, Baker, & Poulin-Dubois, 2002), described in the section "Integration with Existing Research and Theory," support this interpretation of 20-month-olds' data.

In the final two experiments, I assessed infants' ability to associate motion onset and object kind. In Experiment 3, I assessed 16-month-olds' ability to associate one motion onset with mammals and another motion onset with vehicles. Specifically, I assessed infants' ability to associate self-initiated motion onset with mammals and externally caused motion onset with vehicles. Both animals and vehicles had moving functional parts. The vehicle exemplars were of a type that is clearly externally propelled. In the self-initiated motion event the character (animal or vehicle) began to move without being pushed by a lever. In the externally caused motion event the character began to move after being pushed by a lever. The self-initiated and externally caused motion onsets depicted in the events differed only in whether the lever contacted the character when the character began to move. Infants associated neither self-initiated motion onset with mammals, nor externally caused motion onset with vehicles. Experiment 4 was a control experiment to test whether infants were able to discriminate between the presence and absence of contact between the lever and the character. Specifically, I assessed whether 16-month-olds were able to associate one type of motion onset with a particular animal or vehicle. There was no evidence that they were able to do so.

To summarize, the experiments reported in this dissertation yielded two primary findings. First, infants associate trajectories and object kinds by 20 months of age. Second, infants of 16 months of age do not associate motion onsets with either object kinds or individual objects when these types of motion onset are distinguished solely by the presence or absence of contact between a lever and the character. The inability of infants to associate these two types of motion onset with individual objects suggests that infants were unable to discriminate between the presence and absence of contact.

Integration with Existing Research and Theory

Line of Trajectory

In past research, it has been shown that by 6 months of age infants discriminate between lines of trajectory (Sharon & Wynn, 1998; von Hofsten et al., 2000; von Hofsten et al., 1998), and that by 9 or 10 months of age infants categorize animals and vehicles separately using a multiple-exemplar object examining paradigm (Mandler & McDonough, 1993; Oakes et al., 1997) and even earlier using a multiple-exemplar visual habituation paradigm (Arterberry & Bornstein, 2001, 2002), but with the exception of the present experiments only one experiment (Poulin-Dubois & Vyncke, 2002) has tested infants' ability to link trajectory with the emerging animate-inanimate distinction. The present experiments may provide a more valid test of infants' conceptual understanding of animals and vehicles, because interpretation of Poulin-Dubois and Vyncke's (2002) experiment is complicated by the fact that the experimenter and the infant manually moved the miniature replicas of animals and vehicles, with the result that an agent caused both the animate and inanimate motions. Considered together, the results of the two present experiments indicate that the ability to associate different lines of trajectory with object kinds emerges between 16 and 20 months of age. Although these results are consistent with those of Poulin-Dubois and Vyncke, these researchers found a trajectory and object kind association at 14 months. In addition, in my experiments there was weak evidence that infants of 16 months show some ability to associate vehicles with trajectories, whereas the ability to associate animals with trajectories does not emerge until 20 months. No such category difference was found in Poulin-Dubois and Vyncke's experiment. These similarities and differences in results will be examined in more detail and possible explanations for the differences in results between the two projects will be discussed.

It is important to consider that only the jumping trajectory was tested in both projects. When Poulin-Dubois and Vyncke analyzed their data by trajectory, they found that 18-month-olds, but not 14-month-olds, associated the jumping trajectory with animals. Thus, a trajectory-kind association was observed at similar ages in the two research projects when the same trajectory is considered. It is possible that infants' ability to associate trajectories with object kinds emerges gradually and that infants are able to associate some trajectories with object kinds at younger ages than other trajectories. It seems likely that trajectory type is an important variable.

Another potentially important variable is the motion range of members of the two categories. Inanimate objects are less flexible in their motion than are animate objects (Poulin-Dubois & Vyncke, 2002). Generally, inanimate objects engage only in inanimate motion, whereas animate objects engage in both animate motion and inanimate-seeming motion. In the present experiments, infants were sensitive to a change in vehicle trajectory at a younger age than a change in animal trajectory. It should be noted that trajectory and object kind were confounded in these experiments because infants' ability to detect a trajectory-kind violation used only one trajectory per object kind. Poulin-Dubois and Vyncke did not find a tendency for infants to generalize trajectories to vehicles before they generalized trajectories to animals. They did find that, with the exception of 14-month-old girls, infants were more likely to move exemplars along inanimate trajectories. Such spontaneous performance of inanimate trajectories may suggest some level of knowledge of or familiarity with inanimate-type motion trajectories. Caution is warranted in interpreting infants performing more inanimate than animate motions in Poulin-Dubois and Vyncke's experiment as evidence of greater knowledge of inanimate trajectories because there are other possible explanations for this pattern. For example, perhaps the inanimate motions are motorically easier for infants to perform. The evidence obtained in the present experiments that infants are sensitive to a change in vehicle trajectory earlier than a change in animal trajectory is consistent with evidence from generalized imitation experiments that infants draw conceptual distinctions within the vehicle domain at a younger age than within the animal domain

(Mandler & McDonough, 1998). Whether infants associate certain trajectories with categories at younger ages, whether infants associate vehicles with trajectories at younger ages than animals, and the role of the inflexibility of vehicles' motion are empirical question that merit further study.

Although infants in the two research projects associated a jumping trajectory with object kind at a similar age and thus trajectory type may provide the most parsimonious explanation for the age difference when the overall results are compared, two potentially important methodological differences remain between the two experiments. First, the two research projects differed in that in Poulin-Dubois and Vyncke's procedure the experimenter made a distinctive sound while modelling the trajectory with an exemplar, whereas no sound accompanied the presentation of events in the present experiments. Perhaps the addition of a sound in Poulin-Dubois and Vyncke's experiment helped infants focus on the association between trajectories and object kinds. If so, this would be consistent with Quinn and Eimas' (1996, 2000) hypothesis that infants attend to correlations between attributes. It would also be consistent with the inter-sensory redundancy hypothesis proposed by Bahrick (e.g., Bahrick, 1994), in which she argues that infants learn multimodally presented properties before unimodally presented properties. For example, 5-month-old infants discriminate between rhythms that are presented simultaneously in two sensory modalities but do not discriminate between unimodal rhythms (Bahrick & Lickliter, 2000). In the case of object kinds and motion cues such as trajectory, information may be multimodal in the real world. For example, an animal approaching a wall, jumping over the wall, and walking away might be accompanied by the following sequence of sounds: footsteps, no footsteps, footsteps.

Thus, it would be interesting to examine the impact of multimodal information on infants' ability to associate trajectory and object kind.

A second important methodological difference between the two research projects concerns the relative novelty of the test exemplars in the two experiments and how novelty influences the measurement of infants' performance. Infants in Poulin-Dubois and Vyncke's experiment were briefly exposed to the test exemplars during a baseline phase, whereas in the present experiments infants saw the test exemplars only during the test phase. Thus, while novel category members are presented to infants in the test phase of both paradigms, the test exemplars used in Poulin-Dubois and Vyncke's experiment were less novel to infants in their experiment than were the test exemplars to infants in the present experiments. Novelty of the test exemplars could interfere with infants' ability to demonstrate a trajectory-kind association. Note that infants must overcome novelty to apply their knowledge of object kinds in daily life and therefore novelty of test exemplars in some sense reflects infants' real world tasks.

Test exemplar novelty also has a different impact on the measurement of infants' performance in the generalized imitation procedure used by Poulin-Dubois and Vyncke and the visual habituation procedure used in the present experiments. Poulin-Dubois and Vyncke used three-dimensional toy replicas that were manipulated and observed by the experimenter and the infant, whereas in the present experiments, I used two-dimensional animated events that were observed by the infant. In the generalized imitation procedure, infants' performance is measured in terms of whether infants perform the motion with an exemplar and whether the exemplar is a member of the appropriate category for that motion. Infants may spend considerable time exploring the new items both visually and tactilely, thereby overcoming the exemplars' novelty, before choosing an exemplar to perform a motion. Thus, the novelty of the test exemplars may be expected to have a limited impact on the measure of infants' performance. In contrast, in the visual habituation paradigm, infants' performance is measured using the duration of infants' looking at events. In this paradigm, infants' exploration of the novel item is visual and is included in the looking-time measure of infants' performance. Therefore, this visual exploration may add "noise" to the data. Thus, although the use of a novel exemplar in the test phase is standard when testing infant categorization using habituation or familiarization procedures (e.g., Mandler & McDonough, 1993; Oakes et al., 1997; Quinn & Eimas, 1996) and although the type of exemplars used in the present experiments were probably familiar to infants via picture books or daily life, it is possible that the presence of novel category exemplars in the test phase may have impaired infants' performance in the present experiments.

If novelty interfered with infants' performance in the present experiments then one would expect that reducing novelty might improve performance, particularly for younger infants. In a recent follow-up experiment (Demke, 2002; Demke, Baker et al., 2002), test exemplar novelty was reduced by presenting motionless images of these exemplars during the habituation phase. For example, if the test events were a cat jumping and a bus jumping, then in the habituation phase a bus was stationary on the far side of the wall while a dog jumped over the wall and a cat was stationary on the far side of the wall while a car bounced into the wall. Demke (Demke, 2002; Demke, Baker et al., 2002) found that 16- and 20-month-olds looked longer at the incongruent event than at the end of the habituation phase, whereas infants looking times at the congruent event did not differ from the end of the habituation phase. There was a trend for infants to look longer at the incongruent event than at the congruent event. There was no difference between their abilities to associate jumping and bouncing with object kinds. These data suggest that under highly controlled experimental conditions in which infants are familiarized with the test exemplars, infants of 16 months are able to associate trajectory and object kind, although the ability is not entirely robust. It remains to be determined whether younger infants will respond similarly.

Motion Onset

Research on infants' ability to discriminate between causal and non-causal events provides indirect evidence that by 6 months of age infants are beginning to discriminate between self-initiated and externally caused motion and that by 10 months of age this ability is robust (Leslie, 1984a, 1984b; Oakes, 1994; Oakes & Cohen, 1990). To date, only a few experiments have examined infants' understanding of the motion onset appropriate for animate beings and inanimate objects. Woodward et al. (1993, as cited by Spelke et al., 1995) found weak evidence that 7-month-olds expect two inanimate objects to interact with physical contact rather than without physical contact. In contrast, infants of this age reacted similarly to contact and no contact interaction between two people. Poulin-Dubois et al. (1996) found that infants of 9 and 12 months show negative affect when a robot demonstrates self-initiated motion by beginning to move spontaneously, but do not show negative affect when a person moves spontaneously. Golinkoff and Harding (1980, as cited by Golinkoff et al., 1984) found that some 16-month-olds and most 24-month-olds consider self-initiated motion by a chair to be anomalous.

In contrast to this research, 16-month-old infants were found to be unable to associate self-initiated motion onset with mammals and externally caused motion onset with vehicles when these motions differ only in the presence versus absence of contact between the agent and the animal or vehicle. In a control experiment, 16-month-old infants were found to be unable to associate these motion onsets with individual animals and vehicles. Although null results must be interpreted with caution, two alternative interpretations of the control experiment seem probable. Either infants were unable to detect the difference between the motion onsets, or they considered the motion onsets to be equivalent. In either case, the data provide an explanation for infants' inability to associate motion onset and object kind in Experiment 3.

Data were collected in two additional experiments that are relevant to the results of the present experiments. First, another experiment was conducted with 16- and 20-month-olds examining infants' ability to associate mammals with self-initiated motion and vehicles with externally caused motion. In this previous experiment, the exemplars represented broader categories of animate beings (bird, dog) and inanimate objects (shoe, stroller) rather than vehicles and mammals (Baker, Poulin Dubois, & Munoz, 2001; Munoz, 2000). The procedure was identical to that of the experiment reported here in all other respects. As in the present experiment, infants did not associate motion onset with object kind. The consistency of results across these experiments supports the conclusion that infants are unable to associate these particular motion onsets with object kinds and suggests that the results obtained in the present experiment were caused neither by the particular exemplars used, nor by the particular infant sample tested.

Second, an experiment was conducted in which adults saw incongruent events (self-initiated motion by an object and externally caused motion by an animal) from this other study (Munoz, 2000). Adults were asked to describe the events. All 16 adults spontaneously mentioned the contact between the lever and the animal and 12 of 16 adults spontaneously mentioned the lack of contact between the lever and the object. These data indicate that adults detected the contact and lack of contact between lever and character and are in contrast to the data from the control experiment reported here, which suggest that 16-month-olds did not detect the difference between when contact occurred and when it did not.

The data from the two experiments reported in this dissertation will now be considered in light of past research. In the research examining young infants' ability to discriminate between causal and non-causal events, experimenters examined two types of non-causal events in which there was no contact between agent and recipient. Researchers used either a launching-without-collision event, in which there was a spatial gap but no temporal delay between cessation of motion of one block and onset of motion of other block (Leslie, 1984b; Oakes, 1994; Oakes & Cohen, 1990), or a delayed-reaction-without-collision event, in which there was a spatial gap and a temporal delay between cessation of motion of one block and onset of motion of other block (Leslie, 1984b). In the one instance in which both temporal and spatial variables were altered simultaneously, the relationship between the two variables was not perfect. That is, the temporal delay was not equal to the distance that the moving object would have covered had it kept moving. Thus, the use of relative temporal continuity in the self-initiated motion event of the present experiments, in contrast to absolute temporal continuity in most of past experiments, may explain infants' inability to discriminate this event from the externally caused event.

The results of the present experiments on motion onset are in contrast to the results of three experiments examining infants' knowledge of the motion onsets appropriate for animate beings and inanimate objects (Golinkoff & Harding, 1980, as cited in Golinkoff et al., 1984; Poulin-Dubois et al., 1996; Woodward et al., 1993, as cited in Spelke et al., 1995). One key difference between the present experiments and the two experiments providing clear evidence that infants considered a motion onset to be anomalous, those conducted by Poulin-Dubois et al. (1996) and Golinkoff and Harding (1980), is that in the latter experiments there was no plausible source of external force to explain motion onset. Thus, the self-initiated motion was unambiguously self-initiated. In contrast, the infants in the present experiment were required to use the presence or absence of contact between a lever and a character to determine whether the character's motion was self-initiated or externally initiated. I consider the presence of a possible, but non-causal, agent in the self-initiated motion event an important feature of the experimental design. If the lever had been completely absent in the self-initiated motion onset events, it would have created a clear perceptual difference between the self-initiated and externally caused events. Consequently, infants could have formed a simple association between object kind and presence versus absence of the lever during the habituation phase. Thus, in the present experiments infants were required to understand that it is category-inappropriate for an inanimate object to begin to move without physical contact, whereas it is category-appropriate for an animate being to do so. The converse is true for motion onset with physical contact.

A second key difference is that category-inappropriate motion was tested for inanimate objects only in the experiments by Poulin-Dubois et al. (1996) and Woodward et al. (1993), whereas category-inappropriate motion was tested for both animate and inanimate objects in the present research. It is difficult to test infants' understanding of animate beings' motion onset because the biomechanical motion of walking in itself implies an internal cause of motion as each step occurs. Nonetheless, if infants understand that animate beings begin moving in a self-initiated manner, they should find it anomalous for animate beings to move because of a push by an external agent. However, the salience of this manipulation is likely to be weak relative to the overall impression of the event.

The research by Poulin-Dubois et al. (1996) shows that infants of 9 months detect the anomaly of self-initiated motion by an inanimate object when no plausible external agent is present. The present research raises some question regarding whether infants of 16 months are able to detect the anomaly of such motion when a plausible external agent is present. There is reason to question whether the present design was a valid test of this hypothesis, however, because infants did not associate type of motion onset with particular animals and vehicles. This failure suggests that infants were unable to discriminate between the two motion onsets tested, which differed in the presence versus absence of contact between the lever and the character, but did not differ in the temporal continuity between the motion of the lever and character. Unfortunately, the one experiment in which infants were demonstrated to react to the anomaly of a no contact interaction between inanimate objects (Woodward et al., 1993) does not provide details of how the no contact and contact events differ in terms of temporal and spatial variables.

Another key difference between the present experiments and the research of Poulin-Dubois et al. (1996) and Golinkoff and Harding (1980) is that in the latter research typical inanimate objects were used, whereas in the present experiments vehicles were used. Furthermore, the wheels on the vehicles rolled to prevent infants from forming a simple association between object kind and the presence or absence of moving parts. The use of vehicles may have contributed to the difficulty of the task. The moving parts on the animals and vehicles may have also served to attract the attention of infants. Past research has found that the use of complex characters in a causal event makes it more difficult for infants to process the relationship between the characters (Oakes & Cohen, 1990).

The factors mentioned thus far are considered key to explaining the different findings in the present and past research on infants' understanding of how animate beings and inanimate objects move. Specifically, in the present experiments there was: temporal contingency between lever and character in both motion onsets, a plausible agent in both motions onsets, and animals and vehicles were tested. However, other differences between the present and other experiments will be briefly mentioned. First, live events were used in other experiments, whereas two-dimensional cartoons were used in the present experiments. Thus, it is possible that the motion onsets in other experiments were more salient or realistic than in the present experiments. Finally, the dependent variables were very different. In other experiments, infants' ability to detect the anomaly of an inanimate object's self-initiated motion was assessed using infants' emotional response, whereas the in the present experiments, it was assessed using infants' looking time.

A follow-up experiment was conducted recently to control for variables that were hypothesized to have made the present experiment difficult for infants (Poulin-Dubois & Baker, 2002). First, the novelty of the test exemplars was reduced by incorporating motionless images of test exemplars into the habituation events, as was done in the follow-up experiment on motion trajectory. Second, the salience of the motion onset was increased, by increasing the frequency of motion onsets from one to two per event, and by adding a sound which accompanied the moments of motion onset. As discussed in the context of Poulin-Dubois and Vyncke's (2002) experiment on motion trajectory, adding sound could also improve infants' ability to associate motion onset with object kind because it makes motion onset amodal (Bahrick, 1994) and because it adds an additional correlated attribute (Quinn & Eimas, 1996, 2000). Third, the temporal continuity between the lever's motion and the character's motion onset was maintained in the externally caused motion onset event and broken in the self-initiated motion onset event. Specifically, in the externally caused motion event the lever's motion always preceded the motion of the character because the lever moved until it contacted the character and only then did the character begin to move, whereas in the self-initiated motion event the lever began to move after the character was already in motion. Finally, only self-initiated motion onset was used in the test phase, resulting in the vehicle always moving in a category-inappropriate way. We found that infants of both 16 and 20 months looked longer at the incongruent event than at the end of the habituation phase and that there was a trend for infants of both ages to look longer at the incongruent than the congruent event. Thus, with reduced novelty of test exemplars, increased distinctiveness of the externally caused and self-initiated motions, and increased salience of motion onset, infants of 16 months were able to associate type of motion onset with object kind. It is noteworthy that despite the number of changes made, 16-month-olds' ability to associate type of motion onset with object kind was not entirely robust. A goal of future research will be to determine which elements facilitated infants' ability to associate motion onset and object kind.

Theoretical Implications

Infants have been found to categorize animals and vehicles by 9 or 10 months (Mandler & McDonough, 1993; Oakes et al., 1997). Mandler argues that by 7 months of age conceptual processes are at work in categorization tasks (Mandler, 2000a) and she argues in particular for the importance of motion in infants' formation of the categories of animate beings and inanimate objects. Evidence of conceptual categorization in infants of this age has been demonstrated only for infants' ability to generalize activities based on object kind (Mandler & McDonough, 1998).

In the present research, infants were found to associate motion trajectories with object kinds in a robust manner by 20 months of age, with evidence of a nascent ability at 16 months. A subsequent experiment in which the novelty of test exemplars was reduced found evidence of a more developed but not entirely robust ability at 16 months. Infants were not found to associate motion onsets with object kinds by 16 months of age, but this was probably caused by their inability to discriminate the motion onsets tested. In a subsequent experiment under enriched conditions and in which the novelty of test exemplars was reduced, 16-month-olds were found to associate motion onsets with object kinds, but again this ability was not entirely robust. Although younger infants must still be tested, I hypothesize that the ability to associate motion trajectory and motion onset with object kinds emerges between 12 and 16 months of age.

The evidence from the present experiments is consistent with the view that infants' conceptual categories of animate and inanimate objects are based on motion during the second year of life, but it raises questions about Mandler's view that these motion cues are distinguishing features of animate and inanimate categories during the first year (e.g., Mandler, 2000a). Although other motion cues proposed by Mandler (1992a, 1992b) and Rakison and Poulin-Dubois (2001) could be involved in early conceptualization of animals and vehicles, it could also be that such motion cues are not involved in the earliest categories of animals and vehicles. This possibility raises the question of how younger infants' categorize animals and vehicles. It seems likely that perceptual features such as similarity of shape, similarity or presence/absence of parts (Rakison, 2000; Rakison & Butterworth, 1998b), and similarity or presence/absence of facial features (Quinn & Eimas, 1996) are important, particularly very early in life. However, there is already evidence that near the end of the first year infants have some conceptual understanding of these categories because Mandler and McDonough (1998) have found that by 9 months infants are able to generalize activities based on object kind. The activities tested by Mandler and McDonough were ones that would be very familiar to infants. Perhaps infants' earliest conceptual knowledge of animals and vehicles consists of very familiar routines.

The present experiments were not designed to directly pit Mandler's and Quinn and Eimas' views of infant categories against one another. Even so, the results may be examined in light of these theoretical proposals. The evidence that infants do associate motion cues and object kinds is consistent with Mandler's view of the centrality of motion to infants' animate and inanimate categories; however, as discussed above, this association is much later in development than Mandler would predict. It could be argued that Quinn's view would also explain infants' ability to associate motion and object kind because motion is one of the many perceptual features to which he hypothesizes infants attend. The results of the second experiment on line of trajectory, however, are not entirely consistent with Quinn's view either. In that experiment, moving legs were added to the animals and moving wheels were added to the vehicles. Despite this change, infants of 16 months were unable to associate trajectory and object kind, just as was the case in the experiment in which these functional parts did not move. The fact that adding motion to legs and wheels did not facilitate 16-month-olds' ability to associate trajectory and object kind suggests that simply emphasizing a relevant shared perceptual feature does not improve infants' categorization. Quinn's view would not predict this outcome. Furthermore, although Rakison and Poulin-Dubois (2002) found that infants of 14 and 18 months are attuned to the movement of parts on individual geometric objects and Rakison (Rakison, 2000; Rakison & Butterworth, 1998b) has argued for the importance of parts in infants categorization, the present experiments suggest that moving parts do not contribute to infants' understanding of the motions of animate and inanimate objects. It is unclear why this might be so. One possibility is that moving parts of novel objects, but not familiar objects, are salient to infants and therefore for novel objects infants attend to the correlation between trajectory and moving parts. Alternatively, the difference between the results in the present experiment and Rakison and Poulin-Dubois (2002) could indicate that moving parts are used primarily in the identification of individual objects, but do not contribute to category formation.

The present experiments provide evidence that motion may be a component of infants' concepts of animals and vehicles during the second year of life. The evidence is generally consistent with Mandler's views on the importance of motion in infants' animate and inanimate categories, but not in all details. Many questions remain about the mechanism by which categories are created and develop and about the content of these categories. Some suggestions for future research are presented in the next section.

Future Directions

The results of the present experiments suggest a number of directions for future research. Some of these follow directly from the present experiments and concern remaining questions about infants' ability to associate animate beings and inanimate objects with lines of trajectory and types of motion onsets. Others address more generally the role of motion in infants' early understanding of animate beings and inanimate objects.

The present experiments assessed infants' ability to associate motion cues and object kinds and represent one of the first attempts to examine infants' knowledge of the motion of animals and vehicles. If infants are able to form an association between motion cues and object kinds in a laboratory setting this provides evidence that at a minimum infants are sensitive to these variables and can detect a co-variation between them. Furthermore, it is reasonable to conclude that infants may be attending to these variables in their daily lives. In contrast, if infants are unable to form an association between motion cues and object kind it is unlikely that motion is firmly established in their knowledge of animals and vehicles. In the present experiments, infants were found to associate trajectory and object kind at 20 months of age and a follow-up experiment found evidence of this ability at 16 months (Demke, 2002; Demke, Baker et al., 2002). Furthermore, a follow-up experiment to this dissertation indicates that 16-month-old infants have some ability to associate motion onset and object kind when motion onset is emphasized (Poulin-Dubois & Baker, 2002). Therefore, an important question for future research is whether these motion cues are indeed part of infants' conceptual knowledge of animals and vehicles by these ages. Alternatively, the associations demonstrated in these experiments may indicate that infants are sensitive to any correlation between object kinds and either motion trajectory or motion onset and consequently that infants would respond similarly to any arbitrary correlation.

One way to answer these questions is to modify the present procedure, in which infants always saw congruent events in the habituation phase, that is, events in which animals and vehicles moved in a category appropriate manner. These events are presumably familiar to infants because they depict motions that are possible for animals and vehicles in the real world. Therefore, the test-phase event in which the habituation-phase pairing of motion cue and object kind was broken was always an incongruent event. Thus, familiarity during the experimental session was always confounded with familiarity in the real world. This is a common experimental technique in infancy research using the habituation and familiarization paradigms (e.g., Baillargeon, 1995).

To control for the effects of novelty and familiarity, Bogartz, Shinskey and Speaker (1997) have argued that the experimental design should be balanced across infants in terms of the real-world possibility, and therefore familiarity, of the familiarization or habituation events. In such a design, half of the infants are familiarized or habituated with a possible event and half of the infants are familiarized or habituated with an impossible event. The two groups of infants see the same set of test-trial pairs. For infants who see an impossible event during habituation, the changed test event is familiar in the real world and novel in the experimental session and the unchanged test event is novel in the real world and familiar in the experimental session. The converse is true for infants who see a possible event during habituation.

To provide an example of a design that is balanced for the habituation events' possibility, applying such a design to Experiment 2 would mean that half the infants would habituate to the possible (i.e., congruent) events of a dog jumping over the wall and a car bouncing into the wall and half the infants would habituate to the impossible (i.e., incongruent) events of a dog bouncing into the wall and a car jumping over the wall. All infants would see the events listed in Table 2 in the test phase. For example, reading from the first row of the table, some infants would see a cat-jumping event and a bus-jumping event. For infants who saw the dog-jumping and car-bouncing habituation events, the bus-jumping event is both incongruent in a real-world sense and novel in an experimental sense because the habituation-phase association between jumping and animals is broken in this event. For infants who saw the dog-bouncing and the car-jumping habituation events, the bus-jumping event is incongruent in a real-world sense and familiar in an experimental sense because the association between jumping and vehicles is maintained in this event.

By using an experimental design that is balanced in terms of the possibility (i.e., congruence) of the habituation events, the researcher has two ways to test whether infants are learning an arbitrary association between motion cues and object kinds during the experimental session, or infants have pre-existing knowledge of the motions that are typical of animals and vehicles. One way in which the experimenter may determine the basis of infants' looking behaviour is to compare the two infant groups' looking-time patterns at test events. If infants are merely learning an arbitrary association between trajectory and object kind, then infants who saw the incongruent events (dog bouncing, car jumping) in the habituation phase should look longer at the congruent test event (e.g., cat jumping) than at the incongruent test event (e.g., bus jumping) and longer at the congruent test event than at the end of the habituation phase. One would expect this looking-time pattern because for these infants the congruent test event contains a violation of the association between motion trajectory and object kind presented in the habituation phase. This test-phase looking-time pattern is the opposite of the pattern expected for infants who saw congruent events in the habituation phase, who would be expected to look longer at the incongruent test event than at the congruent test event, to dishabituate to the incongruent test event, and not to dishabituate to the congruent test event. If infants who saw incongruent events in the habituation phase and infants who saw congruent events in the habituation phase show the same pattern of looking times then infants must be applying pre-existing knowledge of the motion trajectories of animals and vehicles. More subtly stated, differences between the two groups of infants' patterns of looking times at the test events would reflect some contribution of pre-existing knowledge (Kannass, Oakes, & Wiese, 1999).

Another way in which the experimenter may determine the basis of infants' looking behaviour is to compare the rate at which infants' looking times decline to possible and impossible events (Bogartz et al., 1997). If infants perceive the impossible events as impossible, or more simply as novel in their real-life experience, one would expect that during the habituation phase infants would initially look longer if they were presented with impossible events than if they were presented with possible events (Bogartz et al., 1997; Kannass et al., 1999) and that the rate of decline in infants' looking times during the habituation phase would be slower for impossible than possible events (Bogartz et al., 1997). Given that the present and subsequent experiments have demonstrated that infants are able to associate object kind and motion trajectory (Demke, 2002; Demke, Baker et al., 2002) and object kind and motion onset (Poulin-Dubois & Baker, 2002) by mid-way through the second year of life, the use of a balanced design in future research would provide valuable insight into the basis of these associations.

A second question for future research is whether the present results may be generalized to animate beings other than mammals and inanimate objects other than vehicles. That is, infants may associate line of trajectory or motion onset with other members of these categories earlier or later in development, or more strongly or less strongly at the same age. With respect to the present research, this question is pertinent particularly for line of trajectory because only this motion cue was associated with object kind by infants. One interesting manipulation is to replace vehicles with more typical exemplars of inanimate objects. Vehicles are atypical exemplars of inanimate objects in that their motion may resemble the motion of animate beings. With respect to trajectory, some vehicles may follow non-linear trajectories, such as an airplane becoming airborne or a car swerving around an obstacle. As discussed earlier with respect to motion onset, some vehicles have a source of propulsion that is not salient. Perhaps infants may associate trajectories and motion onsets with more typical inanimate objects at a younger age than with vehicles. Preliminary evidence supporting this hypothesis was obtained in a recent experiment on infants' ability to associate trajectories with object kinds in which furniture, rather than vehicles, was used as exemplars of inanimate objects. Specifically, 20-month-olds were found to react more strongly to trajectory-kind violations in this experiment than in experiments in which vehicles were used (Demke, Hoang, Baker, & Nayer, 2002). To the extent that this manipulation produced data that are predicted by theory and based on distinctions present in the real world, the pattern of data across the experiments suggests that infants are not learning an entirely arbitrary correlation between trajectory and object kind. If it were arbitrary, one would expect that the particular exemplars used would not influence the response of infants.

Another interesting manipulation would be to use less perceptually similar exemplars of animals (e.g., a dog and a snake) and vehicles (e.g., a car and a bicycle) and examine infants' ability to generalize from one exemplar to another. Based on Mandler's theory one would predict that infants should be able to draw inferences regarding motion just as well from a dog to a snake as from a dog to a cat. In contrast, based on Quinn and Eimas' theory one would predict improved performance when perceptual similarity of exemplars is higher.

A third question for future research is to examine whether infants generalize more easily from a human to a non-human animal than from one animal to another. There are several reasons to hypothesize that infants might generalize from a human to an animal at a younger age than from an animal to an animal. Infants are exposed to humans in a variety of contexts on a daily basis. Furthermore, there is evidence that humans are a cognitive reference point by 3 to 4 months of age (Quinn & Eimas, 1998). In addition, there are several pieces of evidence to suggest that infants' knowledge of humans develops earlier than their knowledge of animals. For example, 5- and 7-month-olds have been found to habituate to individual humans, but not to individual animals, patterns that suggest infants recognize individual humans before they recognize individual animals and therefore that young infants may learn to generalize their knowledge of humans to other animate beings (Pauen, 2000). Furthermore, infants of 10 months of age discriminate one versus two objects when humanlike and non-humanlike objects are contrasted, but not when only non-humanlike objects are contrasted (Bonatti, Frot, Zangl, & Mehler, 2002; Xu & Carey, 1996).

A fourth question for future research is whether exposure to multiple category exemplars in the habituation phase would enable infants to associate motion cues with object kind at a younger age. This possibility is suggested by the fact that infants have been demonstrated to categorize by 9 or 10 months of age using an object examining paradigm in which multiple category exemplars are presented in sequence (Mandler & McDonough, 1993; Oakes et al., 1997) and even earlier using a visual habituation paradigm in which multiple category exemplars are presented in sequence (Arterberry & Bornstein, 2001, 2002). Such a modification would move the present paradigm more clearly in the direction of teaching infants an association between a category and a motion cue during the habituation phase, but could be informative regarding the youngest age at which infants are sensitive to correlations between motion cues and object kinds.

A fifth question for future research concerns the realism of the motions used in the present experiments. The biomechanical motion and trajectories were necessarily simplified from those of a real event because they were created using animation. This simplification could be cause for concern regarding whether the present research demonstrated infants' understanding of the motion that is possible of animate beings and inanimate objects. The fact that 16-month-olds' performance in Experiment 2 with ecologically-enhanced stimuli was no better than 16-month-olds' performance in Experiment 1 with impoverished stimuli provides preliminary evidence that the limited realism of the events did not cause the data indicating that the ability to associate trajectory and object kind emerges later than expected. It also provides preliminary evidence that the results of the present research project would generalize to infants' reactions to the actual motions of real animals and vehicles, but further research is clearly needed. Animation was used in the present experiments because it permitted precise control of the events. An alternative would be to film real events, such as a horse jumping over a wall. These events would contain all the necessary elements of biomechanical motion and trajectory. If results with these filmed events were consistent with the present data, it would provide further evidence that infants were not simply learning an arbitrary correlation that has no bearing on the real world. The use of real events would necessarily involve more variability between events than in the present experiments. In addition, there is the problem of how to film incongruent (i.e., impossible) events. Filming animals and vehicles engaged in category-appropriate motion and then digitally replacing the figures of members of the other category could possibly provide a solution. With regard to the motion-onset experiments, a particularly interesting manipulation would be to use real events and to replace the lever with a person or a person's hand. To ensure items were to scale, small animals and objects would need to be used if a person's hand was used. Infants' understanding of other forms of motion onset, which have been examined with preschool children, such as being carried (S. A. Gelman & Gottfried, 1996) or being pulled (Poulin-Dubois & Héroux, 1994), could be examined using this technique.

Another question for future research is to examine the role of rigid versus non-rigid motion in infants' understanding of animate beings and inanimate objects. In the present research, inanimate objects always moved in a rigid manner and animate beings moved in greatly simplified non-rigid manner (with the exception of Experiment 1). That is, rigidity was confounded with category. This was done because the variables of interest in the present experiments were the motion cues of trajectory and motion onset and infants' ability to associate these motion cues with trajectory. It seems likely that rigidity does influence infants' expectations about animal and object motion. For example, if a bus moved in a non-rigid manner like a caterpillar, perhaps infants would expect it to have other properties of an animate being. Thus, the role of rigid versus non-rigid motion in infants' knowledge of animals and object motion is an interesting topic of future research.

A final question for future research is to examine infants' knowledge of the link between object kinds and other motion cues, such as causal role, that have been proposed to be central to infants' emerging animate-inanimate distinction (Mandler, 1992b; Rakison & Poulin-Dubois, 2001). As the volume of research on this topic builds, researchers may find that some motion cues are part of infants' conceptual knowledge at younger ages than other cues and perhaps that some cues are central to the emerging animate-inanimate distinction, whereas other cues are not.

Conclusions

The present research was inspired by the hypothesis that infants' categories of animate and inanimate objects are based on motion cues (Mandler, 1992b; Rakison & Poulin-Dubois, 2001). Infants ranging in age from 12 to 20 months were tested to determine whether they could associate motion trajectories and motion onsets with object kinds. Despite the fact researchers have frequently examined the contrast between animals and vehicles in infant categorization tasks, virtually all research on infants' ability to associate motion cues and object kinds has used only humans as exemplars of animate beings and objects other than vehicles as exemplars of inanimate beings. In the present research, infants were found to associate one non-linear motion trajectory with animals and one linear motion trajectory with vehicles by 20 months of age. There was some evidence of an emerging ability to associate trajectory with object kind at 16 months, which was confirmed in a follow-up experiment in which novelty of stimuli was reduced. Infants were not found to associate self-initiated motion onset with animals and externally caused motion onset with vehicles by 16 months of age, but this was probably caused by their inability to discriminate the motion onsets tested. A follow-up experiment provided evidence that 16-month-olds are able to associate motion onset and object kind when novelty of stimuli was reduced and motion onset was emphasized.

The distinction between animate beings and inanimate objects is fundamental to children's and adults reasoning (e.g., R. Gelman & Spelke, 1981; S. A. Gelman & Opfer, 2002). The present data suggest that this may also be true of infant cognition. Furthermore, motion may be a core attribute of these conceptual categories by the second year of life.

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Appendix A

Highest Level of Education for Parents of Infants Who Participated in Experiment 1

	Age of infant (months)		
Highest level of education (%)	12[a]	16[b]	20[c]
Father			
Some high school or high school degree	17.5	17.1	5.8
Some college	5.0	0.0	0.0
College or vocational degree	30.0	22.0	11.4
Some university	2.5	2.4	5.7
Undergraduate degree	37.5	46.3	54.3
Postgraduate education	7.5	9.8	20.0
Level of education not given	0.0	2.4	2.9
Mother			
Some high school or high school degree	19.5	9.3	11.1
Some college	2.4	2.3	8.3
College or vocational degree	31.7	34.9	22.2
Some university	4.9	4.7	8.3
Undergraduate degree	29.3	30.2	38.9
Postgraduate education	12.2	18.6	8.3
Level of education not given	0.0	0.0	2.8

Note. Data are provided for parents living with the infant. Therefore, the sample sizes of mothers and fathers may differ for a particular infant age. In Quebec, high school ends with Grade 11. Students may then attend college (up to 2 years) followed by university.

[a] Father's education: $n = 40$; mother's education: $n = 41$. [b] Father's education: $n = 41$; mother's education: $n = 43$. [c] Father's education: $n = 35$; mother's education: $n = 36$.

Appendix B Sample Recruitment Letter in English

Concordia
UNIVERSITY

October 1999

Dear Parents,

Our research team is currently conducting research on early understanding of animacy which is funded by the Natural Sciences and Engineering Research Council of Canada. The Commission d'Accès à I'Information du Québec has kindly given us permission to consult birthlists provided by the Régie Régionale de la Santé et des Services Sociaux de la Région de Montréal-Centre. Your name appears on the birthlist of April 1998, which indicates that you have a child of an age appropriate for our study.

At the present time, we would like to invite you and your infant to participate in a research study which we are currently conducting. In this study, we are examining infants' understanding of the differences between the motion of living beings and the motion of non-living objects. During the study your child will be shown films in which objects move across a computer screen. A video camera will be used to record the session, so that we can measure how long your child looks at the films. Participation involves one 30-minute visit to our laboratory at the Loyola Campus of Concordia University, located at 7141 Sherbrooke Street West, at a time which is convenient for you and your child, including weekends. Free parking is available on the campus and we will reimburse any other transportation fees at the time of your appointment. You will receive a Certificate of Merit for Contribution to Science for your child when you participate. In addition, a summary of the results of our study will be mailed to you once it is completed.

For the purposes of this study, we are looking for infants who are 20 months of age, who hear English or French spoken in the home, and who do not have any visual or hearing difficulties. If you are interested in having your child participate in this study, or would like any further information, please contact Rachel at 848-2279 or Dr. Diane Poulin-Dubois at 848-2219. We will try to contact you by telephone within a few days of your receipt of this letter.

Thank you for your interest and collaboration.

Diane Poulin-Dubois, Ph.D.
Associate Professor
Department of Psychology

Rachel K. Baker
Ph.D. Candidate

(français au verso)

7141 Sherbrooke Street West
Montreal, Quebec H4B IR6

Appendix C

Parent Instructions, Parent Consent Form, and Participant Information Form in English

Parent Instructions in English

Instructions for Parents

1. When we enter the room where we will be doing the study, please seat your child in the baby seat and sit behind your child in the chair provided.

2. Before we begin the task, please ensure that your child has no toys or food, as these items may be distracting.

3. During the study, please do not interact with your child. Please do not point at the computer screen or speak to your child.

4. Children often look away from the computer screen from time to time during the study. For example, your child will see some pictures many times and may seem bored. If your child turns to look at you, please **ONLY** smile at him/her. Your child will probably turn to look at the computer after a moment.

5. If your child becomes very fussy or starts to cry, we will stop the study so that you can comfort him/her.

6. Occasionally a child who becomes fussy feels more secure sitting in the parent's lap. If your child does sit on your lap we will ask you to wear a blindfold so that you do not inadvertently guide your child's responses.

Participant Information Form in English

Participant Information

Infant's name:________________________ Date of Birth:_________________________

Gender:_____ Language(s) spoken at home:___________________________________

Mother's name:______________________ Father's name:________________________

Address:___________________________ Telephone #: _____________home

___________________________ _____________work _________

Postal Code:____________ _____________work _________

Mother's occupation:__________________ Father's occupation:____________________

Mother’s education (highest level attained): ____________________________________

Father’s education (highest level attained): _____________________________________

Mother’s marital status: ________________ Father’s marital status: ________________

Please answer the following general information questions about your child:

Birth weight: ____________ Length of pregnancy: ____________ weeks

Birth order: ____________ (e.g., 1 = 1st child)

Were there any complications during the pregnancy? ______________________________

____

Has your child had any major medical problems? ________________________________

____

Does your child have any hearing or vision problems? _____________________________

____

Participant Information (continued)

Please answer the following general information questions about your family:

Does your family have a pet (or pets)? (yes/no) _______ If you answered "yes," please list your pet(s) indicating the kind of pet(s) (e.g., dog, cat, fish) and the number of pets:

____

Subject#: _________ Researcher: ____________________

Consent Form in English

Parental Consent Form

In this study, we are examining how infants distinguish between living beings and non-living objects. More specifically, we are testing their understanding of the motion of members of these two categories. For example, how and at what age do they know that people move differently from chairs? In this study, which takes about 7 minutes, your child will be presented with animated films on a computer screen. The amount of time your child looks at each film will be measured. Your child will be shown two films repeatedly in which something moves across the screen until they begin to lose interest in the films. At that time several different films will be shown. You will be asked to remain silent and neutral during the session. The session will be videotaped and the videotapes and all the data obtained from them will be kept confidential.

____________________	____________________
Diane Poulin-Dubois, Ph.D. Associate Professor	Rachel K. Baker, M.A. Ph.D. Candidate

The nature and purpose of this experiment has been satisfactorily explained to me and I agree to allow my child to participate. I understand that we are free to discontinue participation at any time and that the experimenter will gladly answer any questions that might arise during the course of the research.

____________________	____________________
Parent's signature	Date

I would be interested in participating in future studies with my child (yes/ no): ________

Subject#: _________

Researcher: ____________________

Appendix D

Habituation Events and Sample Incongruent Test Events for Experiment 1

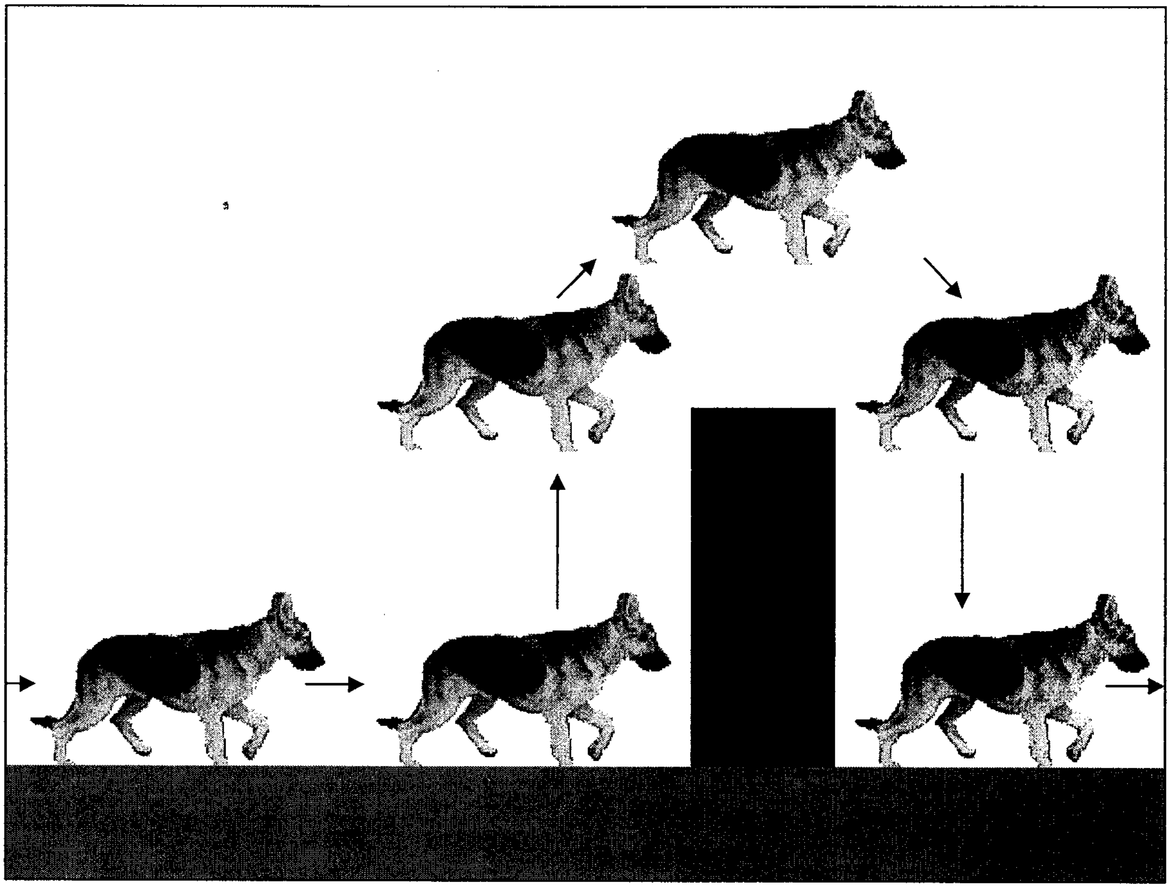


Figure D1. The dog-jumping habituation event presented to infants in Experiment 1.

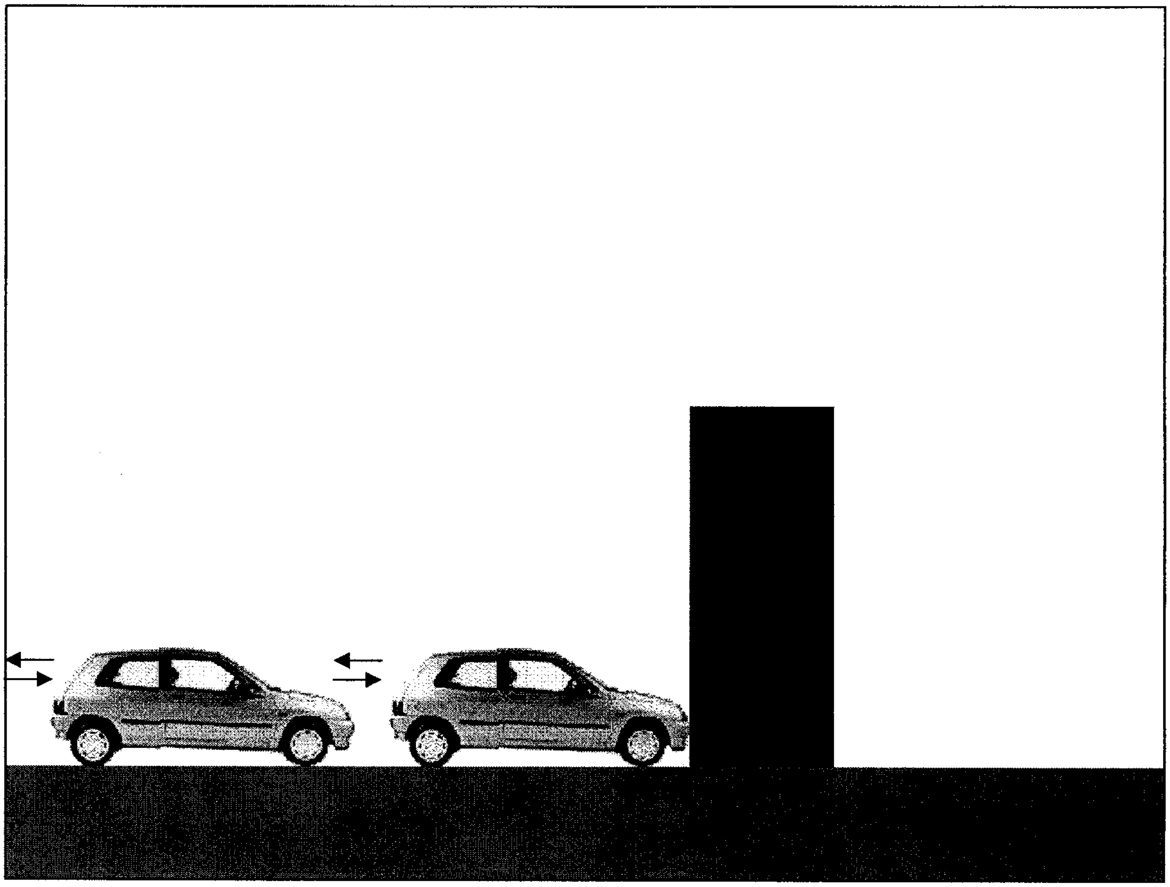


Figure D2. The car-bouncing habituation event presented to infants in Experiment 1.

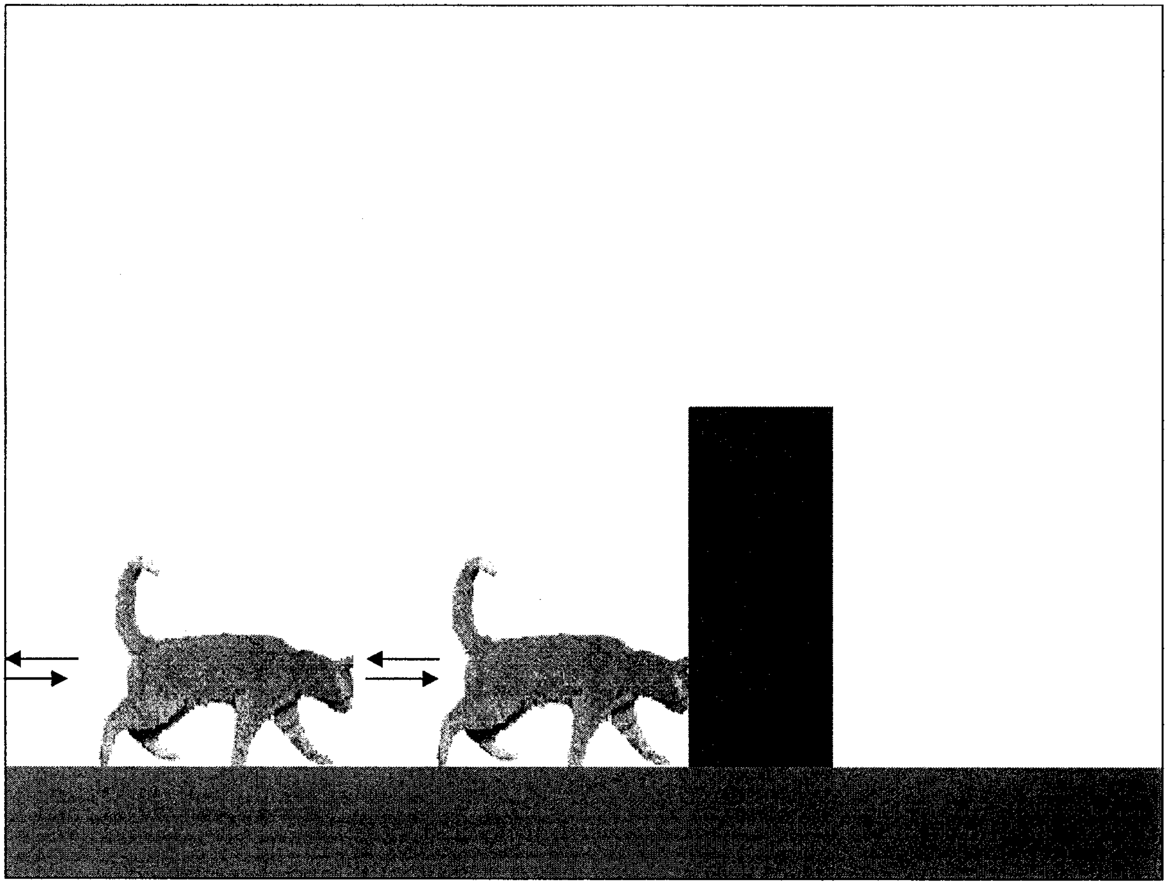


Figure D3. The cat-bouncing test event, one of the animal-bouncing incongruent test events presented to infants in Experiment 1.

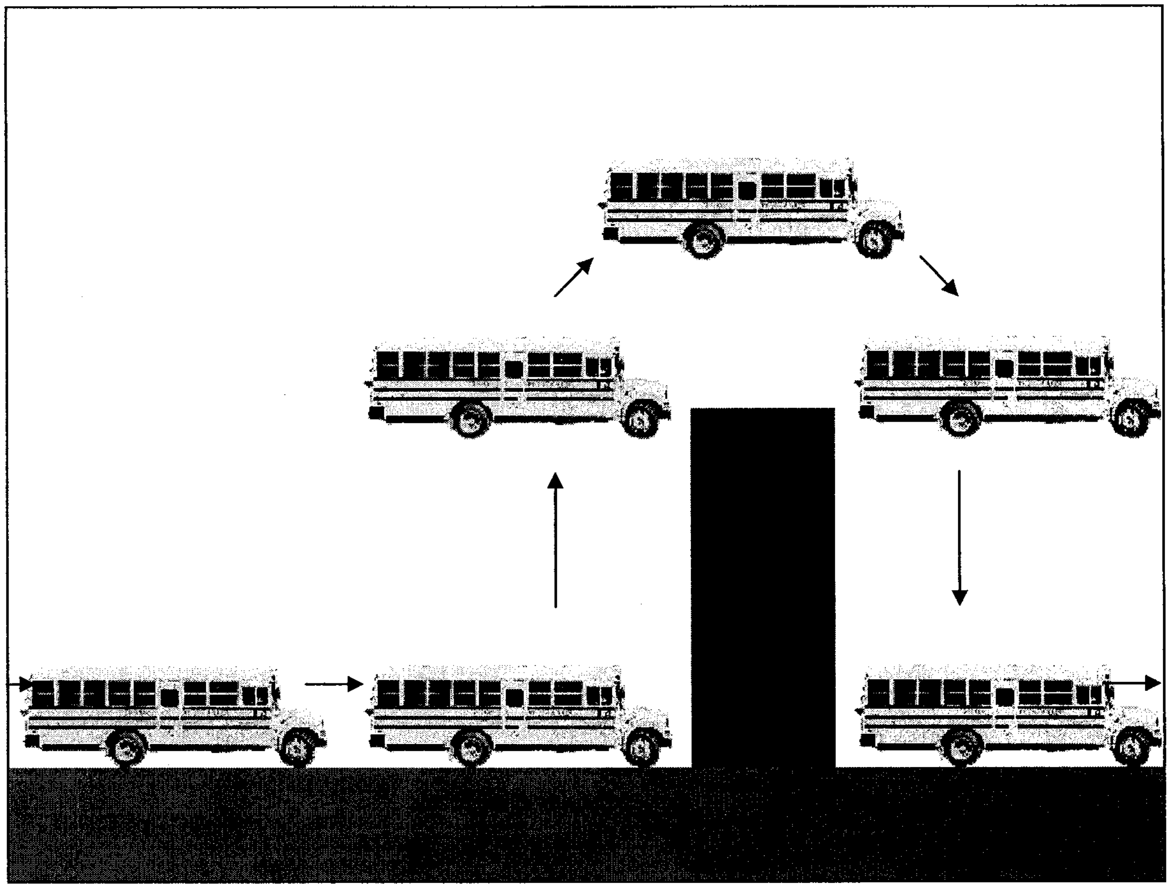


Figure D4. The bus-jumping test event, one of the vehicle-jumping incongruent test events presented to infants in Experiment 1.

Appendix E

Data Screening

Data were examined for normality and outliers by examining each cell in an analysis separately, as recommended by Tabachnick and Fidell (1996). Following Stevens' (1992) recommendation, a criterion of z+/-3.00 was used to identify outliers, except when cells in an analysis were small (i.e., a sub-sample of an age group) in which case a criterion of z+/2.50 was used.

Experiment 1

Inspection of the data revealed that for all planned analyses, one or more of the cells was positively skewed, contained a potential outlier, or was both positively skewed and contained a potential outlier. The breakdown by analysis was as follows, listing only skew and potential outliers:

Habituation block by age analysis of variance. Data for the habituation criterion block of 12-month-olds were positively skewed.

Control by age analysis of variance. Data for the post-test event were positively skewed with an extreme outlier for 12-month-olds and positively skewed for 20-month-olds.

Trial by sex by age analysis of variance. Data for the habituation criterion block were positively skewed and had a potential outlier for both 12-month-old boys and girls. Data for the congruent test event were positively skewed with a potential outlier for 20-month-old girls. Data for the incongruent test event were positively skewed with a potential outlier for 12-month-old girls.

Object kind by age analysis of variance. Data for the animal events were positively skewed with a potential outlier for 12-month-olds. Data for the animal events had a potential outlier for 16-month-olds.

Correcting for Outlier and Skew. An initial attempt was made to correct for potential outliers and positive skew by pulling in the value of potential outliers to the z-score criteria outlined above. This did not correct the skew for 12-month-olds' looking time at the post-test or for 20-month-old girls' looking time at the congruent test event. In addition, two analyses had cells for which the data were skewed, but had no potential outliers. Therefore, I followed Tabachnick and Fidell's (1996) recommendation that, in situations where one has both non-normal variables and potential outliers, it is preferable to first transform variables to achieve normality and then check for remaining outliers. A square-root transformation corrected all instances of positive skew in cells for analyses and all but one potential outlier, looking time at the post-test event by 12-month-old infants. This one value was therefore pulled in after transformation until it was within the $z = 3.00$ criterion. All the analyses for this experiment were conducted using the square-root transformed data because all the analyses were affected by skew.

Experiment 2

The breakdown by analysis was as follows, listing only skew and potential outliers:

Habituation block t-test. No skew and no potential outliers.

Control t-test. Data for the post-test event were positively skewed.

Trial by sex analysis of variance. Data for the incongruent test event were positively skewed with a potential outlier for boys.

Trial by motion analysis of variance. No skew and no potential outliers.

Object kind t-test. Data for the animal events were positively skewed.

Correcting for Outlier and Skew. Only one cell had both positive skew and a potential outlier. It was determined that pulling in the potential outlier to the z-score criterion corrected the skew of this cell. Therefore, this approach was used rather than adjusting all data in the affected analysis using a transformation to correct the skew. A square-root transformation was applied to the two analyses that had skewed data. Computing these two analyses using the original (raw) and transformed data revealed the same result in both cases. Therefore, I chose to report analyses using the original (raw) data. Using the square-root transformed data, the results of these analyses were as follows: (a) Infants looked significantly longer at the post-test ($M = 3.15$, $SD = 1.22$) than at the habituation criterion block ($M = 2.60$, $SD = 0.57$), $t(23) = 2.19$, $p < .05$. (b) There was a marginally significant difference between infants' looking times at the animals ($M = 2.88$, $SD = 1.26$) and the vehicles ($M = 3.50$, $SD = 1.38$), $t(23) = 2.07$, $p = .05$.

Experiment 3

The breakdown by analysis was as follows, listing only skew and potential outliers:

Habituation block t-test. No skew and no potential outliers.

Control t-test. The post-test data were positively skewed.

Trial by group analysis of variance. No skew and no potential outliers.

Trial by sex analysis of variance. No skew and no potential outliers.

Trial by motion analysis of variance. No skew and no potential outliers.

Object kind t-test. No skew and no potential outliers.

Correcting for Outlier and Skew. The results of the t-test comparing mean looking times at the criterion habituation block and the post-test event were the same whether the raw or the square-root transformed data were used. Therefore, the analysis using raw data is reported in text. Using square-root transformed data, the results were as follows: The square-roots of the habituation criterion block (M = 2.66, SD = 0.66) and the post-test event (M = 2.89 s, SD = 1.17) did not differ, *t*(23) = 0.98, p > .05.

Experiment 4

The breakdown by analysis was as follows, listing only skew and potential outliers:

Habituation block t-test. No skew and no potential outliers.

Control t-test. No skew and not potential outliers.

Trial analysis of variance. The data for the incongruent event was positively skewed and the data for the congruent event had a potential outlier.

Object kind t-test. The data for the goat and the stroller were positively skewed and each had a potential outlier.

Correcting for Outlier and Skew. A square-root transformation was applied to the data for the two analyses in which there were skewed cells. This transformation corrected the skew and potential outlier. These analyses were conducted using both raw and square-root transformed data and it was determined that the results were the same. Therefore the analyses using the original data were reported. The square-root transformed results were as follows: (a) Infants' looking times at the habituation criterion block (*M* = 2.72, *SD* = 0.62), congruent test event (*M* = 2.04, *SD* = 0.72), and incongruent test event (*M* = 2.71, *SD* = 1.19) did not significantly differ, *F*(2,22) = 2.01, p > .05, MSE = 090. (b) Infants' looking times at the goat (*M* = 2.22, *SD* = 0.96) and the stroller (*M* = 2.53, *SD* = 1.09) did not significantly differ, *t*(11) = -0.64, p > .05.

Appendix F

Square-Root Transformed Infants' Looking Times in Experiment 1

Table F1

Square-Root Transformed Infants' Looking Times at the Post-test Trial, Habituation Baseline Block and Habituation Criterion Block for Experiment 1 by Age

	Age (months)		
Trial	12	16	20
Habituation Baseline Block			
M	3.45^{b}	3.86^{a,c}	4.28^{d}
SD	0.88	0.87	0.77
Habituation Criterion Block			
M	2.23^{b}	2.32^{c}	2.77^{d}
SD	0.65	0.66	0.57
Post-test			
M	2.33	3.08^{a}	2.72
SD	0.64	0.88	1.29

Note. The values represent square-root transformed looking times measured in square-root seconds. Elements with the same letter differ significantly, $p < .017$. Looking times at the habituation baseline block and the post-test were not compared statistically.

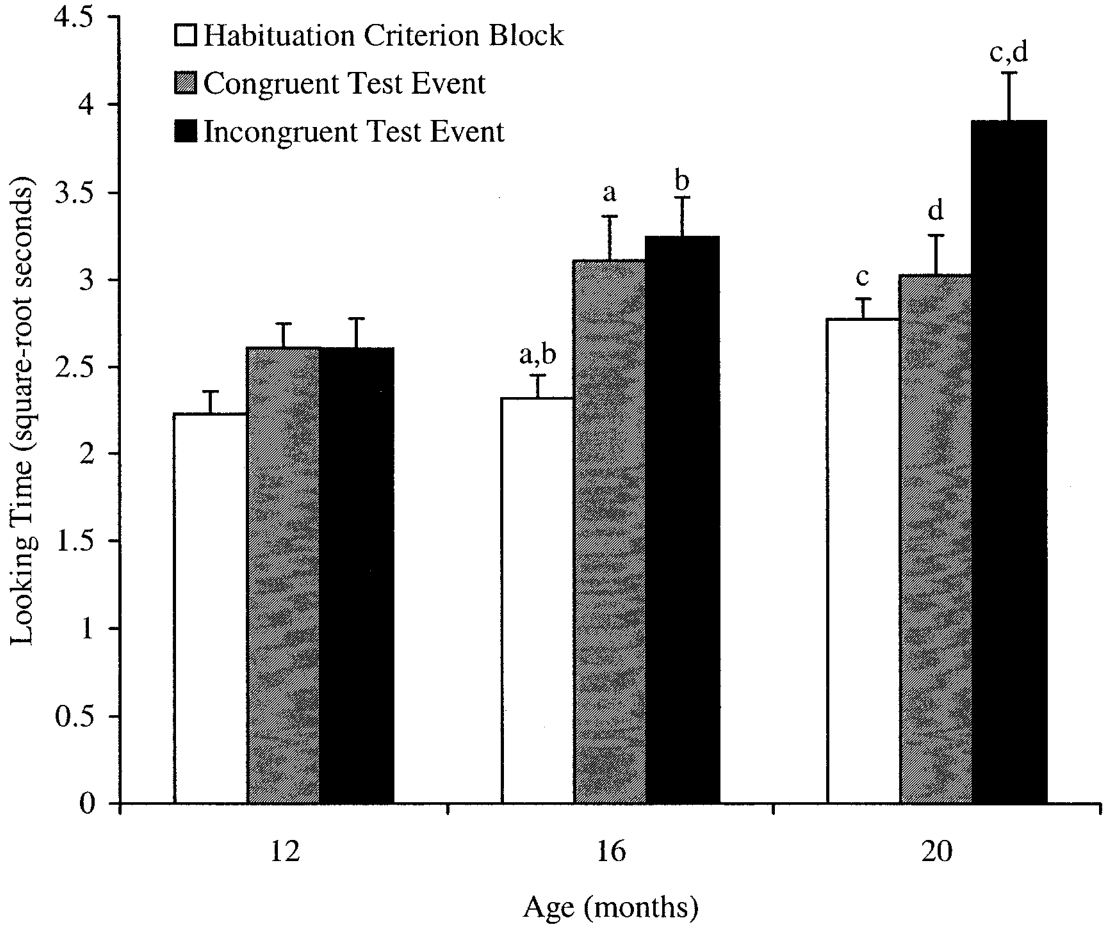


Figure F1. Mean square-root looking times per trial (+*SE*) at the habituation criterion block, congruent, and incongruent events for 12-, 16-, and 20-month-old infants in Experiment 1. For each age, bars labelled with the same letter differ, $p < .017$.

Table F2

Square-Root Transformed Infants' Looking Times at Test Events Collapsed Across the Two Test Events, for Infants in Experiment 1 Who Saw One Animal and One Vehicle In the Test Events, Separately by Age

	Age (months)		
Test Phase	12	16	20
M	2.58	3.05	3.23
SD	0.53	0.92	0.99

Note. The values represent square-root transformed looking times measured in square-root seconds. Elements with the same letter differ significantly, $p < .017$.

Appendix G

Analysis of Variance Tables for Experiment 1

Table G1

Analysis of Variance for Age by Habituation Block in Experiment 1

Source	*df*	*F*
	Between subjects	
Age	2	5.79*
S within-group error	69	(1.00)
	Within subjects	
Habituation Block	1	782.63*
Habituation Block x Age	2	3.84*
Habituation Block x *S* within-group error	69	(0.09)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

**p* < .05.

Table G2

Analysis of Variance for Age by Control in Experiment 1

Source	*df*	*F*
	Between subjects	
Age	2	3.90*
S within-group error	69	(0.82)
	Within subjects	
Control	1	5.05*
Control x Age	2	4.39*
Control x *S* within-group error	69	(0.52)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

$^*p < .05$.

Table G3

Analysis of Variance for Age by Sex by Trial in Experiment 1

Source	*df*	*F*
	Between subjects	
Age	2	6.94*
Sex	1	0.70
Age x Sex	1	1.71
S within-group error	66	(1.30)
	Within subjects	
Trial	2	16.44*
Trial x Age	4	2.54*
Trial x Sex	2	1.76
Trial x Age x Sex	4	0.30
Trial x *S* within-group error	132	(0.73)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

*$p < .05$.

Table G4

Analysis of Variance for Age by Object Kind in Experiment 1

Source	*df*	*F*
	Between subjects	
Age	2	2.57^{t}
S within-group error	45	(1.41)
	Within subjects	
Object Kind	1	0.40
Object Kind x Age	2	1.06
Object Kind x *S* within-group error	45	(1.06)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

$^{*}p < .05$. $^{t}p<.10$.

Appendix H

Highest Level of Education for Parents of Infants Who Participated in Experiment 2

Parent	Highest level of education (%)[a]
Father	
Some high school or high school degree	14.7
Some college	2.9
College or vocational degree	20.6
Some university	0.0
Undergraduate degree	44.1
Postgraduate education	14.7
Level of education not given	2.9
Mother	
Some high school or high school degree	15.8
Some college	0.0
College or vocational degree	34.2
Some university	2.6
Undergraduate degree	36.8
Postgraduate education	10.5
Level of education not given	0.0

Note. Data are provided for parents living with the infant. Therefore, the sample sizes of mothers and fathers differ. In Quebec, high school ends with Grade 11. Students may then attend college (up to 2 years) followed by university.

[a] Father's education: $n = 34$; mother's education: $n = 38$.

Appendix I

Habituation Events and Sample Incongruent Test Events for Experiment 2

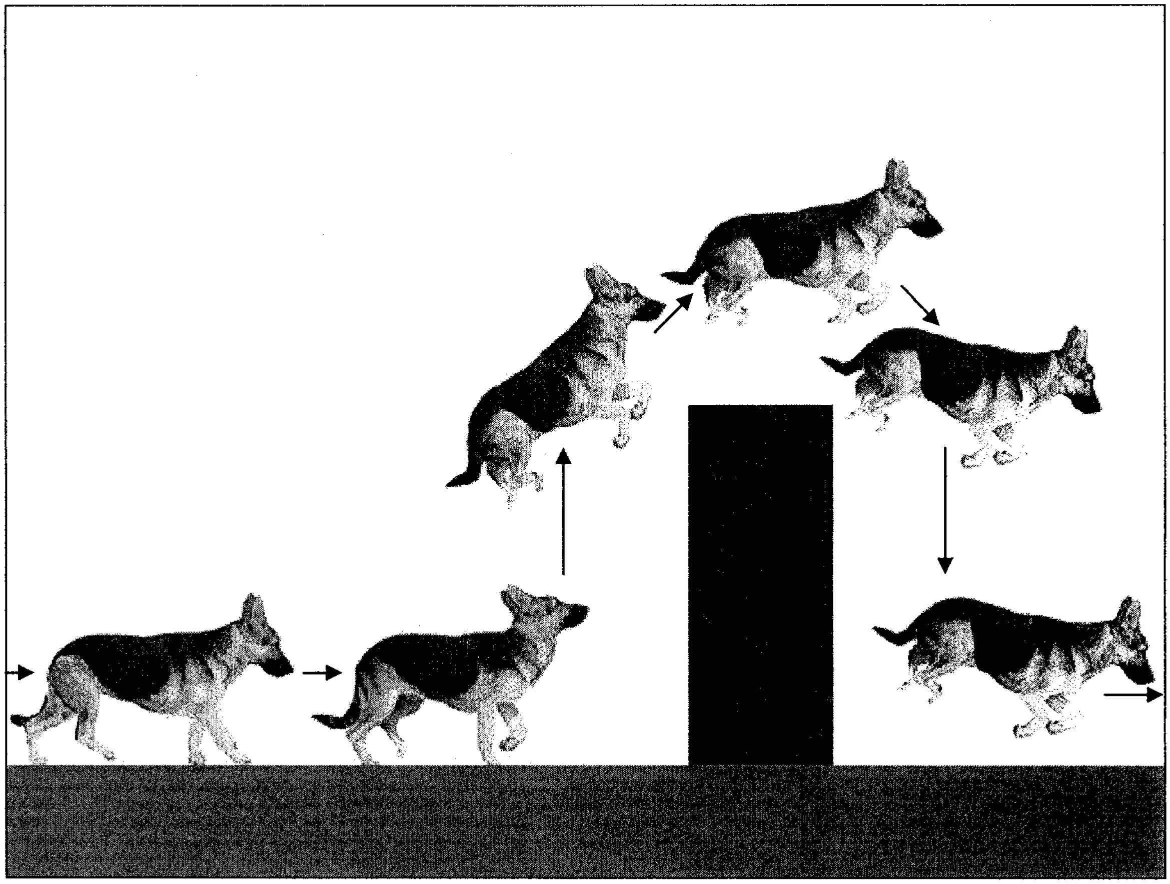


Figure I1. The dog-jumping habituation event presented to infants in Experiment 2.

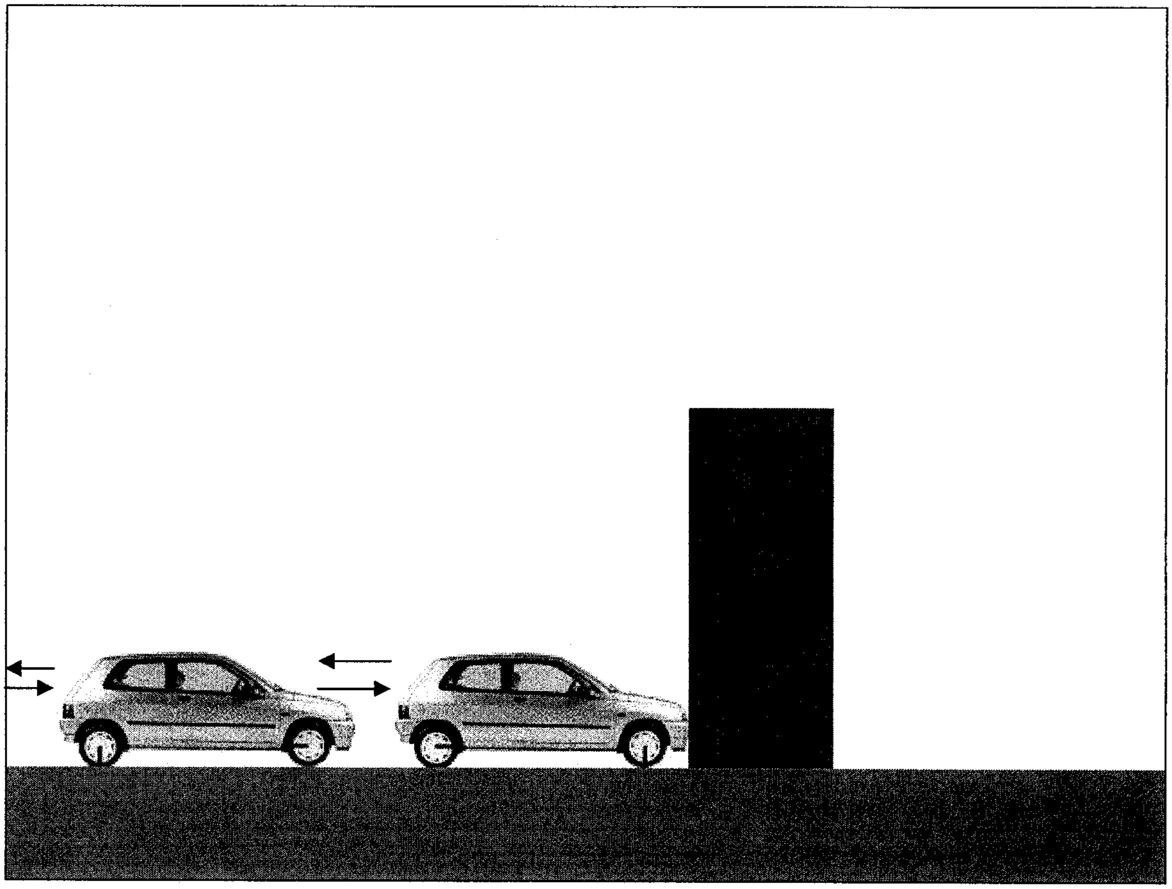


Figure I2. The car-bouncing habituation event presented to infants in Experiment 2.

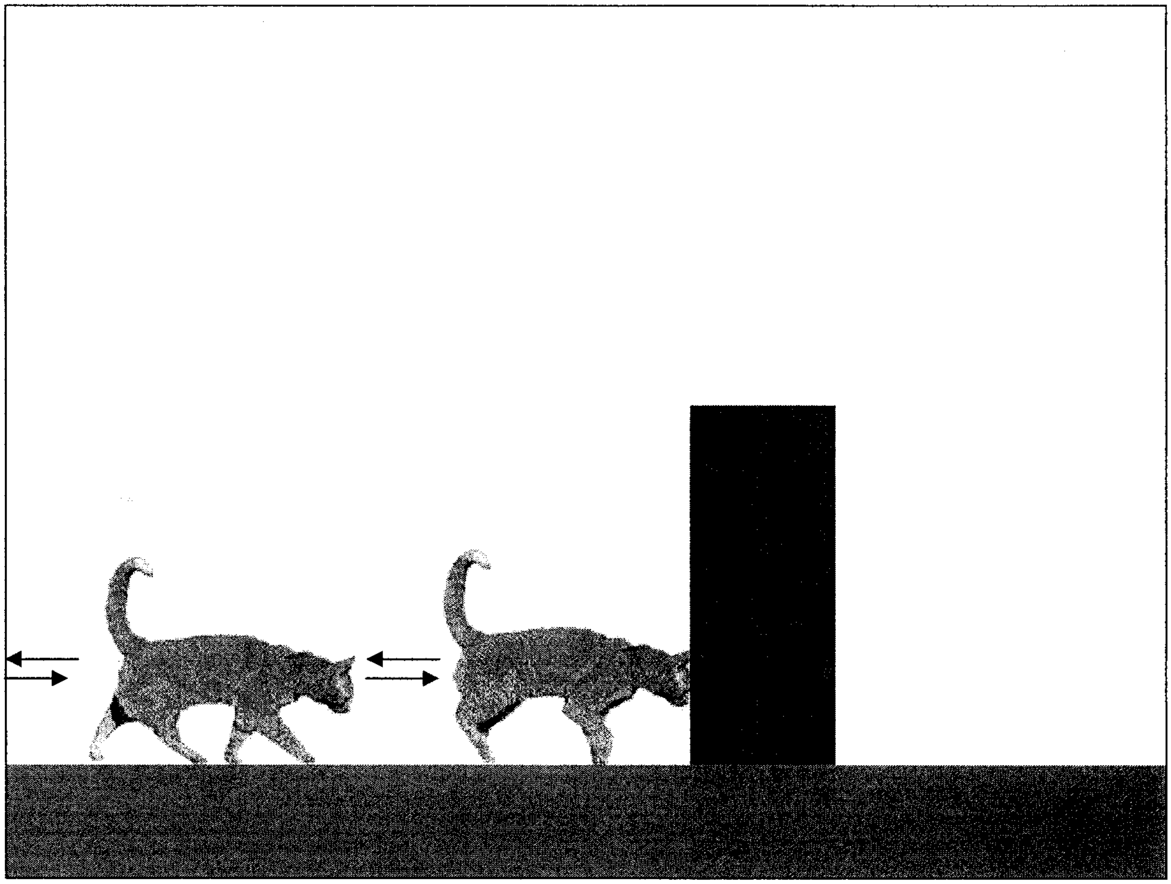


Figure 13. The cat-bouncing test event, one of the animal-bouncing incongruent test events presented to infants in Experiment 2.

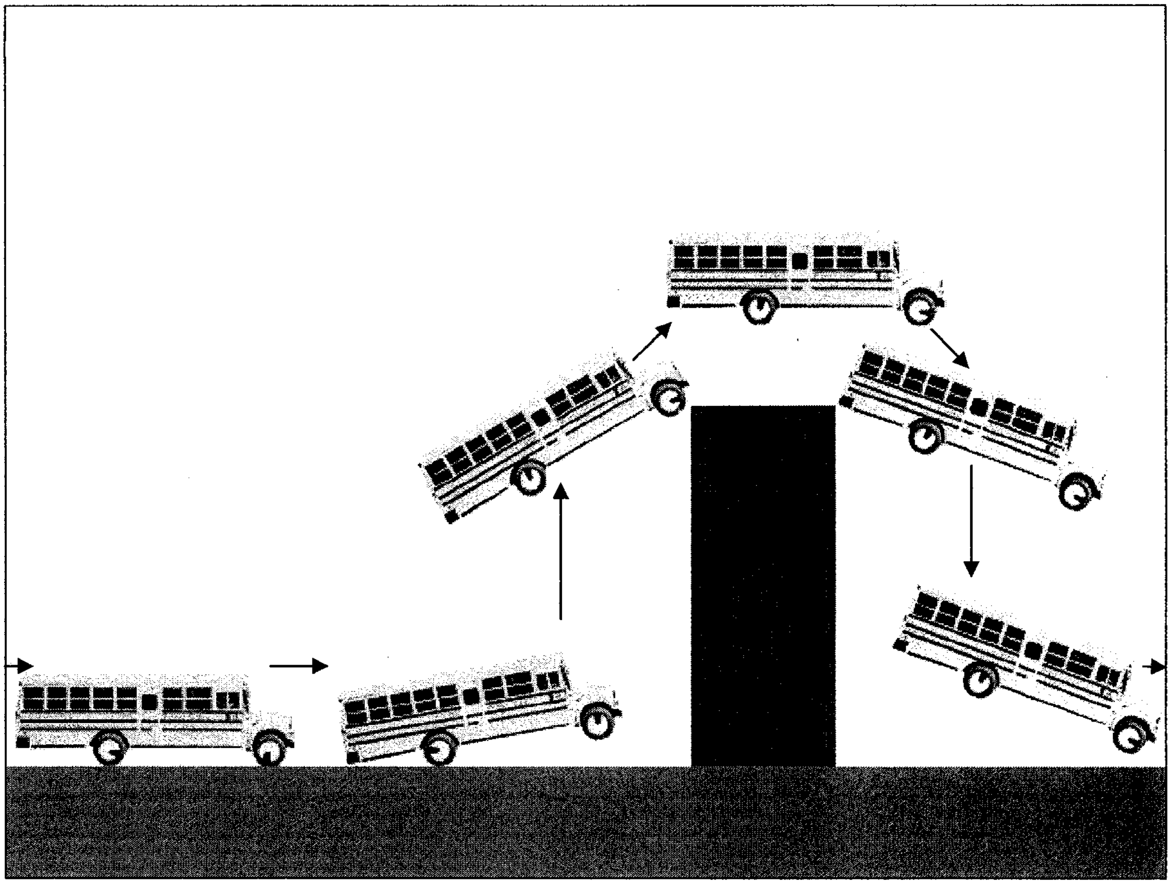


Figure I4. The bus-jumping test event, one of the vehicle-jumping incongruent test events presented to infants in Experiment 2.

Appendix J

Analysis of Variance Tables for Experiment 2

Table J1

Analysis of Variance for Sex by Trial in Experiment 2

Source	*df*	*F*
	Between subjects	
Sex	1	0.53
S within-group error	22	(97.18)
	Within subjects	
Trial	2	5.02^{*}
Trial x Sex	2	1.24
Trial x *S* within-group error	44	(43.25)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

$^{*}p < .05$.

Table J2

Analysis of Variance for Motion by Trial in Experiment 2

Source	*df*	*F*
	Between subjects	
Motion	1	2.42
S within-group error	22	(93.18)
	Within subjects	
Trial	2	5.07^{*}
Trial x Motion	2	2.83^{t}
Trial x *S* within-group error	44	(42.03)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

$^{*}p < .05$. $^{t}p < .10$.

Appendix K

Highest Level of Education for Parents of Infants Who Participated in Experiment 3

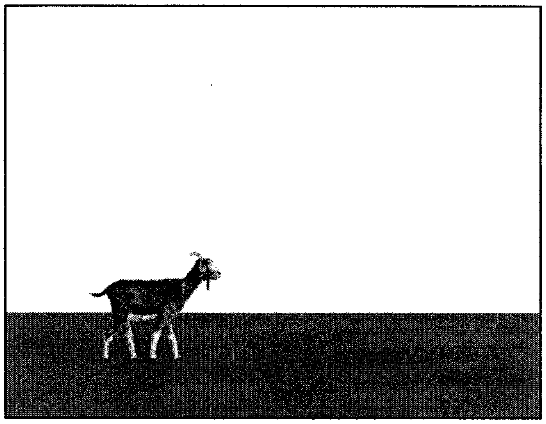
Parent	Highest level of education (%)[a]
Father	
Some high school or high school degree	7.9
Some college	2.6
College or vocational degree	23.7
Some university	7.9
Undergraduate degree	47.4
Postgraduate education	10.5
Level of education not given	0.0
Mother	
Some high school or high school degree	7.7
Some college	5.1
College or vocational degree	28.2
Some university	5.1
Undergraduate degree	43.6
Postgraduate education	10.3
Level of education not given	0.0

Note. Data are provided for parents living with the infant. Therefore, the sample sizes of mothers and fathers differ. In Quebec, high school ends with Grade 11. Students may then attend college (up to 2 years) followed by university.

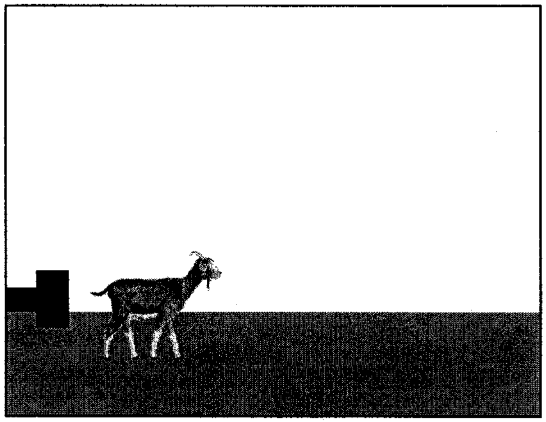
[a] Father's education: $n = 38$; mother's education: $n = 39$.

Appendix L

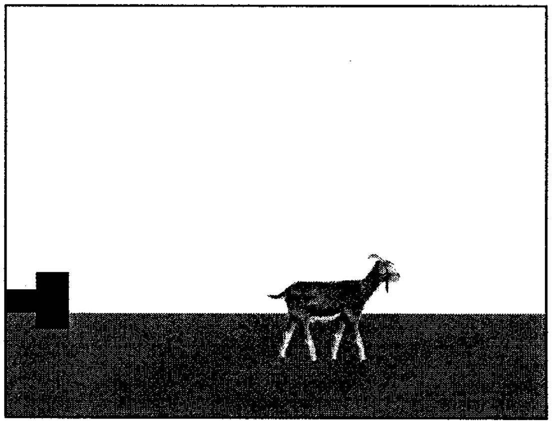
Sample Habituation Events and Incongruent Test Events for Experiment 3



Beginning

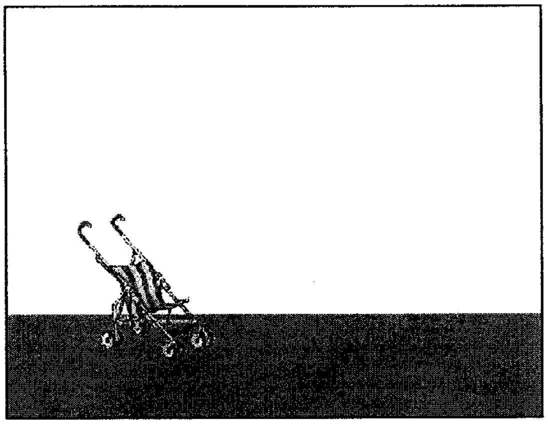


Motion Onset

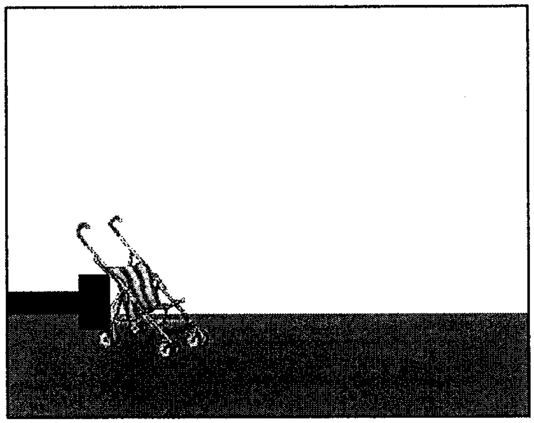


Midpoint

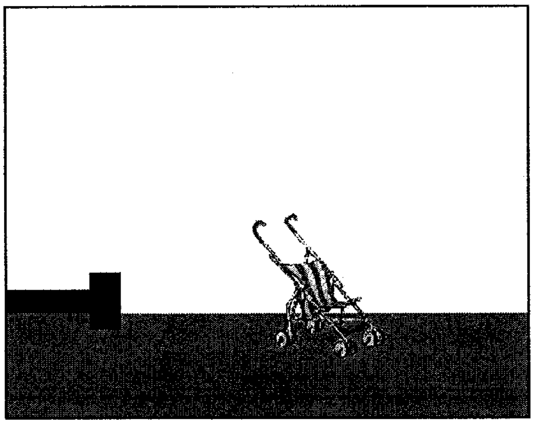
Figure L1. The self-initiated motion-onset goat event, one of the habituation events presented to infants in Group 1 of Experiment 3.



Beginning

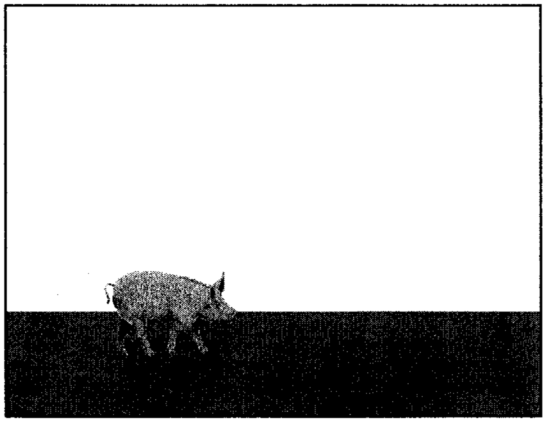


Motion Onset

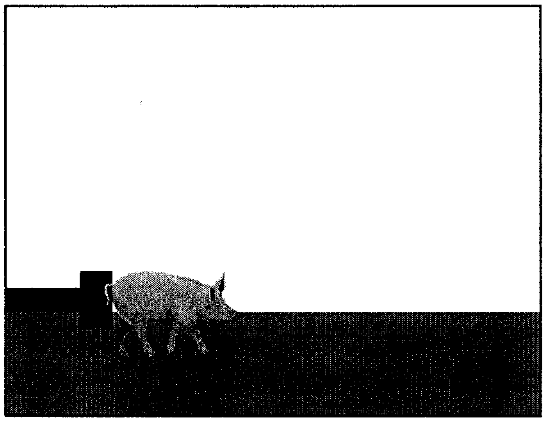


Midpoint

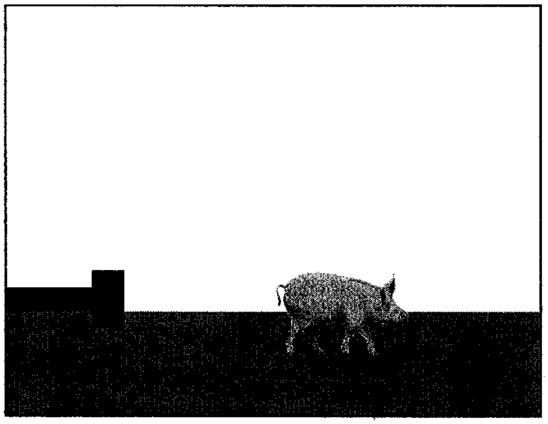
Figure L2. The externally-caused motion-onset stroller event, one of the habituation events presented to infants in Group 1 of Experiment 3.



Beginning

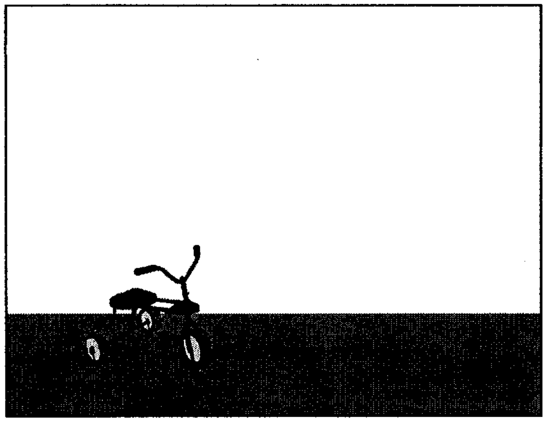


Motion Onset

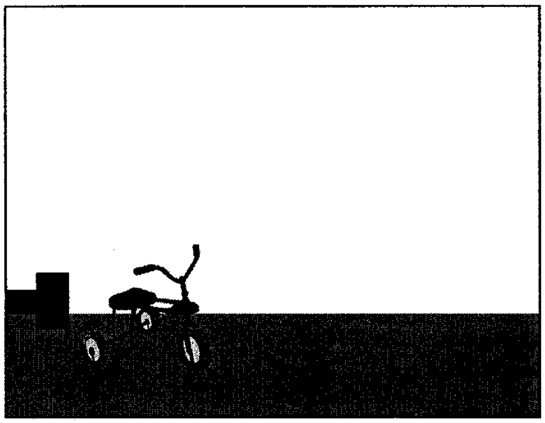


Midpoint

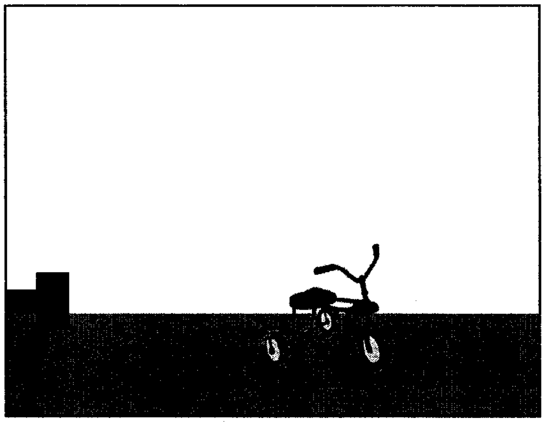
Figure L3. The externally-caused motion-onset pig test event, one of the externally-caused incongruent test events presented to infants in Group 1 of Experiment 3.



Beginning



Motion Onset



Midpoint

Figure L4. The self-initiated motion-onset tricycle test event, one of the self-initiated incongruent test events presented to infants in Group 1 of Experiment 3.

Appendix M

Analysis of Variance Tables for Experiment 3

Table M1

Analysis of Variance for Group by Trial in Experiment 3

Source	*df*	*F*
	Between subjects	
Group	1	0.20
S within-group error	22	(79.60)
	Within subjects	
Trial	2	4.54*
Trial x Group	2	0.51
Trial x *S* within-group error	44	(64.06)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

*$p < .05$.

Table M2

Analysis of Variance for Sex by Trial in Experiment 3

Source	*df*	*F*
	Between subjects	
Sex	1	0.93
S within-group error	22	(80.31)
	Within subjects	
Trial	2	4.51*
Trial x Sex	2	0.69
Trial x *S* within-group error	44	(63.56)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

*$p < .05$.

Table M3

Analysis of Variance for Motion by Trial in Experiment 3

Source	*df*	*F*
	Between subjects	
Motion	1	1.27
S within-group error	22	(75.94)
	Within subjects	
Trial	2	4.44*
Trial x Motion	2	0.18
Trial x *S* within-group error	44	(65.49)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

$^{*}p < .05$. $^{t}p < .10$.

Appendix N

Highest Level of Education for Parents of Infants Who Participated in Experiment 4

Parent	Highest level of education (%)[a]
Father	
Some high school or high school degree	13.3
Some college	0.0
College or vocational degree	26.7
Some university	0.0
Undergraduate degree	53.3
Postgraduate education	6.7
Level of education not given	0.0
Mother	
Some high school or high school degree	13.3
Some college	0.0
College or vocational degree	26.7
Some university	6.7
Undergraduate degree	46.7
Postgraduate education	6.7
Level of education not given	0.0

Note. Data are provided for parents living with the infant. In Quebec, high school ends with Grade 11. Students may then attend college (up to 2 years) followed by university.

[a] Father's education: n = 15; mother's education: n = 15.

Appendix O

Analysis of Variance for Trial in Experiment 4

Source	*df*	*F*
	Within subjects	
Trial	2	1.69
Trial x *S* within-group error	22	(31.29)

Note. Values enclosed in parentheses represent mean square errors. *S* = subjects.

$^{*}p < .05$.