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## Infant Behavior and Development

# Infants' ability to associate motion paths with object kinds

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## ABSTRACT

The goal of the present research was to examine whether infants associate different paths of motion with animate beings and inanimate objects. An infant-controlled habituation procedure was used to examine 10–20-month-old infants' ability to associate a non-linear motion path (jumping) with animals and a linear (rebounding) motion path with vehicles (Experiment 1) and furniture (Experiment 2). During the habituation phase, infants saw a dog jumping over a barrier and either a vehicle or a piece of furniture rebounding off the barrier. In the test phase, infants looked longer when another inanimate object jumped rather than rebounded, but showed no such differential looking in the case of another animate object. The ability to restrict the animate motion path of jumping to animate beings was present by 10 months of age. The present findings support the hypothesis that motion path is associated with the animate–inanimate distinction early in infancy.

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## 1. Introduction

The capacity to recognize and categorize things in one's surroundings as animate beings (humans and other animals) or inanimate objects (artefacts such as vehicles and furniture) is a fundamental cognitive ability (R. Gelman & Spelke, 1981; Opfer & S. Gelman, 2011; Rakison & Poulin-Dubois, 2001; Shutts, Markson, & Spelke, 2009). Developmental research has established that the animate–inanimate distinction is conceptually important by the preschool years (for a review, see Opfer & S. Gelman, 2011). For example, preschoolers determine quite accurately whether animals and objects are alive, attribute biological processes to humans and not to objects (Opfer & S. Gelman, 2011), 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 the extent of preschoolers' understanding of this distinction, it is of empirical and theoretical interest to study its developmental origin in infancy.

A wealth of research conducted over the past 20 years provides evidence that even infants have some grasp of the animate-inanimate distinction (Rakison & Poulin-Dubois, 2001). In one of the first studies of animate and inanimate categories in infancy, Mandler and Bauer (1988) found evidence that 16- and 20-month-old infants could categorize dogs vs. cars (different superordinate-level categories: vehicle and animal), but not cars vs. trucks (same superordinate-level category). The authors took this to suggest that sensitivity to superordinate-level (animals vs. artefacts) categories develops before sensitivity to basic-level categories (types of artefacts or animals). Similar results were found by Mandler, Bauer, and McDonough (1991) with 18–30-month-old infants. In a recent sequential touching study that systematically examined categorization at four different levels of inclusiveness in 12–30-month-old infants, categorization at the most inclusive level (e.g., ducks, lions, pigs, and porpoises categorized as 'animals') was above chance by 18 months of age, but even the youngest infants categorized

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at the less inclusive levels if the categories showed a high perceptual contrast (e.g., helicopters and trucks categorized as 'vehicles'; Bornstein & Arterberry, 2010). Another set of studies provided further evidence for the primacy of superordinate-level categories with even younger infants using an object examination task (Mandler & McDonough, 1993, 1998a). Both 9- and 11-month-old infants were found to categorize superordinate-level categories of animals and vehicles, with 7-month-old infants demonstrating a slightly lower level of performance than the older infants.

Other authors have obtained converging evidence for the developmental primacy of the broad animate-inanimate distinction using longitudinal designs (Pauen, 2002b; Poulin-Dubois, Graham, & Sippola, 1995). More recently, Poulin-Dubois, Frenkiel-Fishman, Nayer, and Johnson (2006) used a generalized imitation procedure to examine whether infants would extend motion and sensory properties modelled on people to animal exemplars (i.e., within the animate category). Both 16- and 20-month-old infants were more likely to extend animate actions to the animal exemplars than to the vehicle exemplars, providing some evidence for the presence of a broad category of animate objects. Similarly, infants as young as 14 months group animals and people together when a sequential task is used (Rostad, Yott, & Poulin-Dubois, 2012). Researchers have also begun to investigate what type of representation is associated with each object kind in preverbal infants. Most developmental psychologists agree that the preverbal animate–inanimate distinction is grounded in perceptual experience with both static features (e.g., appearance of objects) and dynamic features (e.g., properties involving movement). One prominent view of the developmental origin of the animate–inanimate distinction is that infants categorize animate beings and inanimate objects by attending to motion cues. Mandler (1992a, 1992b, 2000, 2011) has proposed 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 path, and interacting contingently with other entities at a distance. Infants might use several motion cues to identify and classify animate beings: (a) self-propelled motion onset, (b) irregular motion path, (c) action produced at a distance, (d) highly contingent motion, and (e) role of agent in causal interactions. Conversely, infants might use different motion cues to identify and classify inanimate objects: (a) caused motion onset, (b) smooth motion path, (c) action produced only by contact, (d) non-contingent motion, and (e) role of recipient in causal interactions (Mandler, 1992b). Some research has investigated whether infants expect animals to move according to animate motion properties. For example, self-propelled motion has been found to be associated with human hands and animals by 7 months of age (Markson & Spelke, 2006; Pauen & Träuble, 2009; Poulin-Dubois, Lepage, & Ferland, 1996; Saxe, Tenenbaum, & Carey, 2005). Path, the trajectory a figure takes with respect to a reference or ground object, has been proposed as one of the first motion property that infants represent (R. Gelman, 1990; Mandler, 1992b) and has also been the focus of some research. Infants as young as 7 months discriminate between silent, simple animated events in which the path of the event changes and can abstract the invariant path even when other features of the display are changing (such as manner of motion) by 10 months (Pruden, Roseberry, Göksum, Hirsh-Pasek, & Golinkoff, 2013; Pulverman, Song, Hirsh-Pasek, Pruden, & Golinkoff, 2013). By 14 months, infants tend to choose an item from the same category as the model to imitate a dog jumping over an obstacle and a car sliding down a ramp (Poulin-Dubois, Rakison, & Vyncke, 1999; Poulin-Dubois et al., 2006; Rakison, 2003). However, this technique may be inappropriate to test conceptual knowledge about animate motion because the experimenter causes all of the objects to move, violating one critical property of animate motion (Mandler, 2003). Furthermore, some authors have argued that generalized imitation of motion events could be explained by matching based on perceptual similarity (Rakison, 2003 but see Mandler & McDonough, 1996, 1998b; Poulin-Dubois et al., 2006 for conflicting results). The generalized imitation technique also poses a challenge for testing infants younger than 12 months (Mandler & McDonough, 1998b). Therefore, whether motion path and animacy are linked in infancy should be tested using paradigms with minimal task demands, such as violation of expectancy. In addition, whether infants younger than 14 months associate motion path and object kind should be tested. These issues were addressed in the present experiments.

The goal of the present experiments was to examine whether infants are able to associate one motion cue, motion paths, with the categories of animals, vehicles, and furniture. We tested infants' ability to associate a non-linear or irregular motion path with animals and a linear or smooth motion path with vehicles and furniture. The irregular path was jumping over an obstacle; the smooth path was hitting an obstacle and rebounding. We used motion paths because even young infants are able to discriminate between motion paths. For example, using a familiarization procedure, Sharon and Wynn (1998) found that 6-month-olds are able to discriminate between jumping and falling.

We used animals (mammals) as exemplars of animate beings and both furniture and vehicles as exemplars of inanimate objects for several reasons. First, researchers have frequently used animal–vehicle and animal–furniture contrasts when testing infants' ability to categorize at a global level. Researchers have found that infants categorize animals and vehicles during the first year of life, by 9 or 10 months when tested using an object examination procedure (Mandler & McDonough, 1993; Oakes, Coppage, & Dingel, 1997) and by 3 months when tested using a visual habituation procedure (Arterberry & Bornstein, 2001, 2002). Similarly, infants categorize animals and furniture during the first year of life, by 7 or 8 months when tested using an object examination procedure (Mandler & McDonough, 1998a; Pauen, 2002a, 2002b) and by 2–3 months when tested using a visual familiarization/habituation procedure (Behl-Chadha, 1996; Quinn & Johnson, 2000). Another consideration was that, in contrast to the research on infant categorization, typically only humans have been used as exemplars of animate beings in studies examining infants' knowledge of the motion of animates and inanimates. Thus,

our choice of category exemplars was designed to bridge the gap between research on categorization in infancy and research on detection of animacy cues in infancy.

In the present experiments, an infant-controlled habituation paradigm was used to test infants' ability to associate different object kinds with different motion paths. In Experiment 1, we tested 10-, 12-, 16-, and 20-month-olds' ability to associate motion paths with animals and vehicles. In Experiment 2, we tested 10-, 12-, 16-, and 20-month-olds' ability to associate motion paths with animals and furniture.

## 2. Experiment 1

In the habituation phase of Experiment 1, infants saw repeated presentations of two events in which a category exemplar moved along a plausible trajectory. In the animal event, a dog jumped over a wall. In the vehicle event, a car hit the wall and rebounded. Each event also included a stationary exemplar from the contrasting category; subsequently, this exemplar would be presented in the test phase. That is, during the dog jumping event a stationary vehicle (e.g., a bus) was present on the screen and during the car rebounding event a stationary animal (e.g., a cat) was on the screen. In the test phase, infants saw an event featuring this vehicle (e.g., a bus) and an event featuring this animal (e.g., a cat); in these events they moved along a trajectory. In the *congruent* test event, the category exemplar followed the same trajectory as the moving category exemplar in the habituation phase (e.g., a cat jumped over the wall in the test phase, just as the dog jumped over the wall in the habituation phase). In the *incongruent* test event, the category exemplar did not follow the same trajectory as the moving category exemplar in the habituation phase (e.g., a bus jumped over the wall in the test phase, whereas the car hit the wall and rebounded in the habituation phase). Thus, the design was a modified form of Cohen's switch design (e.g., Younger & Cohen, 1986). If infants can associate trajectories with these categories of objects, then one would expect them to detect the break in association in the incongruent test event and look longer at the incongruent event than at the congruent event.

### 2.1. Method

#### 2.1.1. Participants

The final sample consisted of 96 infants, 24 in each of four age groups: 10-month-olds ($M = 10.25$ months, $SD = 0.58$; 13 boys, 11 girls), 12-month-olds ($M = 12.54$ months, $SD = 0.25$; 14 boys, 10 girls), 16-month-olds ($M = 16.22$ months, $SD = 0.36$; 12 boys, 12 girls), and 20-month-olds ($M = 20.30$ months, $SD = 0.51$; 12 boys, 12 girls). Infants were recruited from birth records provided by a government health agency. We sent parents a letter describing the experiment and then contacted them by telephone. Infants had a minimum 35-week gestation and no auditory or visual problems, as reported by parents. Most infants were from families of middle socioeconomic status.

Additional infants participated in Experiment 1, but their data were excluded from the analyses. For 10-month-olds, the data of 35 infants were excluded because the infant did not habituate (17), looked at one test trial for less than 1 s (2), fussed (9), or because of parent interaction with the infant (1), experimenter error (5), or technical difficulties (1). For 12-month-olds, the data of 18 infants were excluded because the infant did not habituate (9), looked at one test trial for less than 1 s (1), fussed (4), or because of parent interaction with the infant (2), experimenter error (1) or technical difficulties (1). For 16-month-olds, the data of 15 infants were excluded because the infant did not habituate (6), looked at one test trial for less than 1 s (3), fussed (4), or because of technical difficulties (1), or experimenter error (1). For 20-month-olds, the data of 12 additional infants were excluded because the infant did not habituate (4), looked at one test trial for less than 1 s (3), fussed (4), or because of experimenter error (1).

#### 2.1.2. Apparatus

The infant sat in a child seat attached to a table. A parent sat behind the infant. The infant and parent faced the middle panel of a 3-sided black wooden partition that enclosed parent, infant, and table. Events were displayed on a colour Apple Multiple Scan 720 Display computer monitor (40.6 cm on the diagonal) 1 m in front of the infant. The Apple monitor was connected to a Power Macintosh G3 computer outside the partition. A Sony Trinitron Colour Video monitor (19.7 cm on the diagonal), and a Sony EVO-120 video camera were also outside the partition. The lens of the video camera was focused on the infant's face through a hole in the partition 20 cm above the Apple monitor. The experimenter used the Sony monitor to observe the infant's visual fixation and recorded this information by pressing keys on the computer keyboard.

#### 2.1.3. Stimuli

The experimental stimuli were animated events created using Macromedia Director computer software and exported as QuickTime[TM] movies. Each event contained a light blue background, a brown floor, and a dark blue wall (9.4 cm tall and 4.0 cm wide) in the middle of the floor. In each event, an animated, colour image of a familiar animal (approximately 4 cm tall and 6 cm wide) or vehicle (approximately 3 cm tall and 8 cm wide) moved across the computer screen.

In animal events, the animal emerged on one side of the screen and walked up to the wall: its legs moved, and its body bobbed up and down. The animal either jumped over the wall and departed the screen on the opposite side (*jumping* motion) or hit the wall and moved backwards until it departed from the screen on the side from which it entered (*rebounding* motion). The vehicle events were analogous. The vehicle emerged on one side of the screen and rolled up to the wall: the rolling of the

wheels was indicated by a line on each wheel that rotated as the vehicle moved across the screen. Next, the vehicle jumped over the wall, or hit the wall and rebounded. Animal and vehicle events lasted 8.0 s.

To ensure that the jumping motion was perceived as category-appropriate for animates and that the rebounding motion was perceived as category-appropriate for inanimates, adults were asked to judge the animacy of the jumping and rebounding motions presented to infants. In the events presented to adults, the animal/vehicle was replaced by an arrow, to ensure that the exemplar's category did not influence adults' ratings. Thirty-eight adults (13 males, 25 females) saw either the jumping event or the rebounding event. Adults were asked to give an example of something that follows this motion path. In addition, they were asked to indicate the extent to which they agree with the statement "The arrow moves like an animal moves" and the statement "The arrow moves like an object moves" by using a 10-point Likert scale with 0 (completely disagree) and 10 (completely agree) for each statement. The data from 5 adults were excluded from analysis because their response to the first question was not a noun. Adults who saw the jumping event were significantly more likely to provide an example of an animate being than would be expected by chance (12/16 adults, binomial $p = .038$). In contrast, no adults who saw the rebounding event provided an example of an animate being for the rebounding event (0/17 adults, binomial $p < .001$). Furthermore, adults rated the jumping event as being more like how an animal moves ($M = 7.0$, $SD = 3.1$) than the rebounding event ($M = 2.9$, $SD = 2.7$), $t(31) = 6.17$, $p < .001$ and the rebounding event as being more like how an object moves ($M = 8.2$, $SD = 1.8$) than the jumping event ($M = 4.2$, $SD = 3.73$), $t(31) = -4.02$, $p < .001$. Thus, adult ratings confirmed that the jumping motion is typical of animate beings and the rebounding motion is typical of inanimate objects.

An additional stimulus (the *attention-getter*) was used to reorient the infant's gaze to the computer screen. In this event, a green circle expanded and contracted on a black background, and the sound of a bell ("ding") was repeated once per second.

### 2.1.4. Design and procedure

An infant-controlled habituation procedure was used to present infants with computer animations. The attention-getter was presented prior to each trial; the trial began when the infant looked at the screen. During a trial, one event (8.0 s) was presented repeatedly, with repetitions separated by a green curtain (1.0 s). A trial continued until the infant looked away from the screen for 1.0 s after looking at the screen for a minimum of 0.5 s, or until the event had repeated four times. The maximum trial length was thus 35 s (8 s event + 1 s curtain + 8 s event + 1 s curtain + 8 s event + 1 s curtain + 8 s event).

In the habituation phase, infants saw two events repeatedly: a dog jumping over the wall, and a car hitting the wall and rebounding. Thus, the dog followed a motion path expected of animals and the car followed a motion path expected of vehicles (see Fig. 1 for habituation and test events). To control for the novelty of the animal and vehicle exemplars featured in the test events, each exemplar was included in a habituation event. The test exemplar always belonged to the contrasting category. That is, the habituation event featuring a jumping dog included a vehicle test exemplar (truck or bus), and the habituation event featuring a rebounding car included an animal test exemplar (cat or horse). The test exemplar was positioned on the far side of the screen from which the dog or car emerged. To familiarize infants with the stationary test exemplar on both sides of the screen and to control for directionality across the animal and vehicle events in the habituation phase, during half of the habituation trials the dog or car moved from left to right on the screen and during half of the habituation trials the dog or car moved from right to left on the screen.

The habituation phase consisted of a maximum of 16 trials, 8 dog jumping and 8 car rebounding. Half of the infants saw the dog jumping in the first trial and half saw the car rebounding in the first trial. During the first four trials, the dog/car moved from left to right and from right to left on alternate trials. Subsequently, a given event and direction of motion was presented no more than twice in a row. The habituation phase ended when the infant's total looking time during four successive trials was less than 50% of that during the first four habituation trials, or after a maximum of 16 trials.

In the test phase each infant saw two events. In the congruent event, an animal or vehicle followed the trajectory portrayed by that category in the habituation phase (e.g., a cat jumped over the wall). In the incongruent event, an animal or vehicle followed the trajectory portrayed by the contrasting category in the habituation phase (e.g., a bus jumped over the wall). Thus, in the congruent event the category–trajectory association was maintained, whereas in the incongruent event the category–trajectory association was violated. Children saw either a test event featuring a cat and a test event featuring a bus, or a test event featuring a horse and a test event featuring a truck. Children saw the same motion path in both test events, with half of the children seeing jumping events and half seeing rebounding events. The order of test events was counterbalanced across children.

### 2.1.5. Coding and inter-observer agreement

The experimenter coded infants' looking times at the events on-line, and was blind to the events presented on the computer screen. Infants' looking times were measured to the nearest 0.1 s. A second coder independently coded the videotapes of 6 (25%) randomly selected infants of each age in the final sample. To determine the reliability of on-line coding, infants' looking times as determined by the two coders were compared using Pearson correlations. Correlations for individual infants ranged from .95 to 1.00.

### 2.2. Results

For both experiments, the dependent variable was infants' cumulative looking time during each trial. Data were screened for normality, outliers, and homogeneity of variance. An alpha level of .05 was used for all analyses. Post hoc analyses were
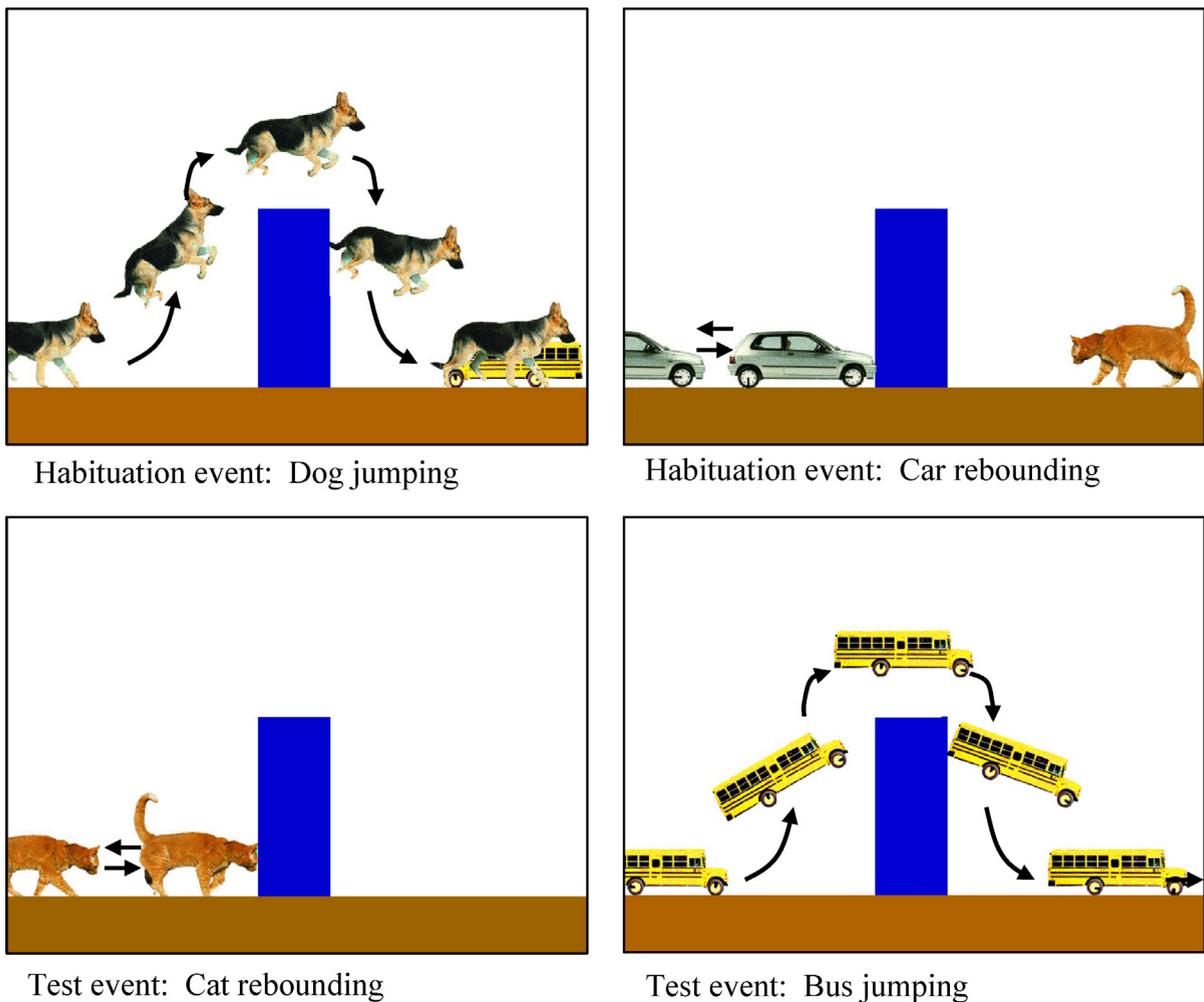
**Fig. 1.** Composites of still frames extracted from the habituation and incongruent test events for Experiment 1.

conducted using pair-wise comparisons with a Bonferroni correction; SPSS Bonferroni adjusted *p*-values are reported for these comparisons.

### 2.2.1. Preliminary analyses

Preliminary analyses were conducted to examine the impact of participants' sex. All the analyses reported below were conducted including sex as a variable. The only significant main effects of sex or interactions with sex were for one measure of habituation responding: A $2 \times 2 \times 4$ (Sex $\times$ Motion $\times$ Age) analysis of variance revealed that boys looked longer at the first four habituation trials ($M = 21.56$ s, $SD = 8.26$) than girls ($M = 16.12$ s, $SD = 7.16$), $F(1, 80) = 13.37$, $p < .001$, $\eta^2_{partial} = .14$. Because sex was not of primary interest in this research and did not interact with any other variables, it was dropped from subsequent analyses.

### 2.2.2. Habituation phase

Infants' mean looking times are summarized in Table 1. Infants' habituation responding was assessed using the mean number of trials to reach criterion and infants' mean looking time during the first four habituation trials. The mean number of trials to reach criterion was assessed using a $2 \times 4$ (Motion $\times$ Age) analysis of variance, which revealed only a significant effect of age, $F(3, 88) = 2.74$, $p = 048$, $\eta^2_{partial} = .09$. Post hoc analyses indicated that 20-month-old infants habituated in fewer trials ($M = 8.3$ s, $SD = 2.8$) than 16-month-olds (M = 10.4 s, SD = 3.0). Infants' mean looking times during the first four habituation trials was compared using a $2 \times 4$ (Motion $\times$ Age) analysis of variance, which revealed no significant effects or interactions.

### 2.2.3. Primary analyses

The primary question of interest was whether infants responded by looking longer at the incongruent event (animal rebounding and vehicle jumping) than the congruent event (animal jumping and vehicle rebounding) in the test phase, and

**Table 1**
Habituating infants' mean looking times (s) during habituation and test trials in Experiments 1 and 2 across age groups.

| Experiment | Habituation trials | | Test trials | | | | | |
|---|---|---|---|---|---|---|---|---|
| | First 4 | Last 4 | Jumping animal | Rebounding animal | Rebounding vehicle | Jumping vehicle | Rebounding furniture | Jumping furniture |
| Experiment 1 | 19.05 (8.18) | 7.80 (3.59) | 9.22 (7.56) | 9.25 (8.68) | 8.06 (6.91) | 13.02 (9.88)[*] | – | – |
| Experiment 2 | 18.56 (7.90) | 7.74 (3.50) | 11.13 (9.37) | 9.75 (8.67) | – | – | 7.47 (6.72) | 13.73 (9.28)[**] |

*Note*: Standard deviations in parentheses.
[*] Different from rebounding vehicle, $p = .004$.
[**] Different from rebounding furniture, $p < .001$.

whether this pattern was found for both animals and vehicles. To answer this question, a $2 \times 2 \times 4$ (Category $\times$ Motion $\times$ Age) mixed analysis of variance was conducted, with Category being a repeated measure comparing infants' looking times at the animal and vehicle test events. This analysis revealed a trend for infants to look longer at jumping test events ($M = 11.12$ s, $SD = 7.52$) than at rebounding test events ($M = 8.65$ s, $SD = 6.15$), $F(1, 88) = 3.48$, $p = .067$, $\eta^2_{partial} = .04$. This trend was modified by a significant Motion $\times$ Category interaction, $F(1, 88) = 6.56$, $p = .012$, $\eta^2_{partial} = .07$. Post hoc analyses revealed that infants looked longer at jumping vehicles ($M = 13.02$ s, $SD = 9.88$) than at rebounding vehicles ($M = 8.06$ s, $SD = 6.91$), $p = .004$. There was no significant difference between infants' looking times at rebounding animals ($M = 9.25$ s, $SD = 8.68$) and jumping animals ($M = 9.22$ s, $SD = 7.56$), $p = .989$. There was also a significant effect of Age, $F(3, 88) = 5.25$, $p = .002$, $\eta^2_{partial} = .15$. Post hoc analyses indicated that 20-month-olds looked significantly longer at test events ($M = 14.09$ s, $SD = 7.06$) than did both 10-month-olds ($M = 7.54$ s, $SD = 5.96$) and 12-month-olds ($M = 7.74$ s, $SD = 4.76$), $p = .005$ and $p = .007$, respectively. These data indicate that infants responded to the jumping vehicle event as more novel than the rebounding vehicle event, but did not respond to the rebounding animal event as more novel than the jumping animal event; these patterns suggest that they detected the violation of the category–trajectory pairing for vehicles only.

A second analysis was conducted including data from participants who did not habituate: The pattern of results was similar to the analysis including only children who habituated: The analysis revealed a trend for infants to look longer at vehicle test events ($M = 10.47$ s, $SD = 9.07$) than at animal test events ($M = 9.12$ s, $SD = 7.96$), $F(1, 124) = 3.22$, $p = .075$, $\eta^2_{partial} = .03$. The analysis also revealed a significant effect of motion, whereby infants looked significantly longer at jumping test events ($M = 11.10$ s, $SD = 7.97$) than at rebounding test events ($M = 8.56$ s, $SD = 6.03$), $F(1, 124) = 4.70$, $p = .032$, $\eta^2_{partial} = .04$. These patterns were modified by a significant Motion $\times$ Category interaction, $F(1, 124) = 6.31$, $p = .013$, $\eta^2_{partial} = .05$. Post hoc analyses to this significant interaction revealed that infants looked longer at jumping vehicle test events ($M = 12.89$ s, $SD = 9.98$) than at rebounding vehicle test events ($M = 8.19$ s, $SD = 7.50$), $p = .003$. In contrast, infants' looking times at rebounding animal test events ($M = 8.93$ s, $SD = 7.93$) and jumping animal events ($M = 9.31$ s, $SD = 8.05$) did not differ, $p = .712$. There was also a significant effect of Age, $F(3, 124) = 5.66$, $p = .001$, $\eta^2_{partial} = .12$. Post hoc analyses revealed that 20-month-olds looked longer at test events ($M = 14.08$ s, $SD = 8.11$) than did both 10-month-olds ($M = 7.39$ s, $SD = 5.28$) and 12-month-olds ($M = 9.00$ s, $SD = 6.11$), $p = .001$ and $p = .019$, respectively. These data indicate that infants who did and did not habituate demonstrated the patterns of longer looking at the jumping vehicle event than the rebounding vehicle event and no significant difference between looking times at the rebounding animal event and jumping animal event.

## 2.3. Discussion

In Experiment 1, infants aged 10–20 months looked longer at an incongruent category–trajectory association involving a vehicle (e.g., bus jumping) than at a congruent category–trajectory association involving a vehicle (e.g., bus rebounding). No such difference was found for animals. The results of Experiment 1 indicate that infants aged 10–20 months responded to the jumping vehicle event as more novel than the rebounding vehicle event, but did not respond to the rebounding animal event as more novel than the jumping animal event. These patterns suggest that infants detected the category–trajectory violation for vehicles only and that by 10 months of age infants are able to associate a motion path with the category of vehicles. This asymmetry in infants' sensitivity to the path of vehicles relative to the path of animals is consistent with the fact that the motion of inanimate objects is more constrained, and therefore more predictable, than the motion of animate beings because the former is determined solely by physical laws whereas the latter is determined not only by physical laws but also by agency.

Research using the generalized imitation paradigm has demonstrated that infants aged 14 months and older prefer to imitate a toy animal jumping over an obstacle and a vehicle sliding down a ramp using a same-category toy (Poulin-Dubois et al., 1999, 2006; Rakison, 2003). The violation of expectancy paradigm allowed us to extend these findings to children as young as 10 months, but differ from results with the generalized imitation procedure in that we found evidence that infants' expectations concerning motion path were constrained for a vehicle but not for an animal. One possible explanation for the divergence in results for animals using the two paradigms is that, as mentioned previously, in the generalized imitation paradigm the experimenter and child must cause the toy to move, which is category-typical for inanimate objects, but not for animate objects.

In Experiment 2, we replaced the vehicles as exemplars of inanimate objects with more prototypical inanimate objects: furniture. One way in which furniture is more prototypical of inanimate objects is that furniture, unlike vehicles, typically does not display moving parts as it moves through space. Using this different category of inanimate objects, we again examined whether infants can associate motion paths with animate beings and inanimate objects.

## 3. Experiment 2

In Experiment 2, we tested 10-, 12-, 16-, and 20-month-olds' ability to associate trajectories with animals and furniture using the same stimuli and procedure as in Experiment 1. Furniture is a typical inanimate object in that, like most inanimate objects, it moves only after being contacted by another object, or does not move at all (R. Gelman & Spelke, 1981). The movement of furniture is a particularly good instantiation of inanimate motion in that it has an evident external cause, for example, a person pushing a chair closer to a table. In addition, furniture has no moving parts. Thus, there is no motion within the furniture itself that could be mistakenly construed as internally caused. In contrast, from an infant's perspective most vehicles appear to move on their own.

### 3.1. Method

#### 3.1.1. Participants

The final sample consisted of 96 infants, twenty-four 10-month-olds ($M = 10.17$ months, $SD = 0.69$, 11 boys and 13 girls), twenty-four 12-month-olds ($M = 12.56$ months, $SD = 0.53$; 11 boys, 13 girls), twenty-four 16-month-olds ($M = 16.19$ months, $SD = 0.52$), and twenty-four 20-month-olds ($M = 20.17$ months, $SD = 0.44$; 13 boys, 11 girls). Infants were recruited in the same manner and had the same demographics as for Experiment 1.

Additional infants participated in Experiment 2 but their data were excluded from the analyses. For 10-month-olds, the data of 15 additional infants were excluded because the infant did not habituate (12), fussed (2), or because of parent interaction with the infant (1). For 12-month-olds, the data of 27 additional infants were excluded because the infant did not habituate (13), looked at one test trial for less than 1 s (1), fussed (7), or because of parent interaction with the infant (2), experimenter error (1) or technical difficulties (3). For 16-month-olds, the data of 22 additional infants were excluded because the infant did not habituate (4), looked at one test trial for less than 1 s (2), fussed (12), or because of parent interaction with the infant (3), or experimenter error (1). For 20-month-olds, the data of 10 additional infants were excluded because the infant did not habituate (3), fussed (3), or because of parent interaction with the infant (1) or experimenter error (3).

#### 3.1.2. Apparatus, stimuli, design, and procedure

The apparatus, stimuli, design, and procedure were identical to Experiment 1, except that furniture was used instead of vehicles. Specifically, a chair was used instead of a car in one of the habituation events. For test items, a table was used instead of a bus and a bed was used instead of a truck. As in Experiment 1, the applicable furniture test item was embedded in the dog jumping habituation event and the applicable animal test item was embedded in the chair jumping habituation event.

#### 3.1.3. Coding and inter-observer agreement

The reliability of the experimenter's on-line coding was determined in the same manner as for Experiment 1. Correlations for individual infants ranged from .90 to 1.00.

### 3.2. Results

#### 3.2.1. Preliminary analyses

Preliminary analyses were conducted to examine the impact of participants' sex. As in Experiment 1, all reported analyses were conducted including sex as a variable in the analysis. The only significant main effects of sex or interactions with sex were for one measure of habituation responding: mean looking time at the first four habituation trials. A $2 \times 2 \times 4$ (Sex × Motion × Age) analysis of variance revealed a significant interaction between Sex and Age, $F(3, 80) = 4.64$, $p = .005$, $\eta^2_{\text{partial}} = .15$. Post hoc analyses revealed that 10-month-old boys looked significantly longer at the first four habituation trials ($M = 21.93$ s, $SD = 8.32$) than 10-month-old girls ($M = 13.05$ s, $SD = 7.71$), $p = .007$. There was also a trend for 12-month-old girls to look longer (M = 20.94 s, SD = 8.29) than 12-month-old boys ($M = 14.98$ s, $SD = 8.29$), $p = .051$. Because sex was not of primary interest in this research and did not interact with any other variables, it was dropped from subsequent analyses.

#### 3.2.2. Habituation phase

The mean number of trials that infants required to reach criterion was assessed using a $2 \times 4$ (Motion × Age) analysis of variance, which revealed no significant main effects or interactions. An analysis of infants' mean looking times during the first four habituation trials using a $2 \times 4$ (Motion × Age) analysis of variance also revealed no significant main effects or interactions. Infants' mean looking times are summarized in Table 1.

*3.2.3. Primary analyses*

A $2 \times 2 \times 4$ (Category $\times$ Motion $\times$ Age) mixed analysis of variance was conducted to examine infants' looking at the test events. Category was a repeated measure comparing infants' looking times at the animal and furniture test events. This analysis revealed a significant effect of motion, with infants looking longer at jumping test events ($M = 12.43$ s, $SD = 7.85$) than at rebounding test events ($M = 8.61$ s, $SD = 6.24$), $F(1, 88) = 6.71$, $p = .011$, $\eta^2_{partial} = .07$. This effect was modified by a significant Motion $\times$ Category interaction, $F(1, 88) = 6.14$, $p = 015$, $\eta^2_{partial} = .07$. Post hoc analyses revealed that infants looked longer at jumping furniture events ($M = 13.73$ s, $SD = 9.28$) than at rebounding furniture events ($M = 7.47$ s, $SD = 6.72$), $p < .001$; in contrast, infants' looking times at rebounding animal events ($M = 9.75$ s, $SD = 8.67$) and jumping animal events ($M = 11.13$ s, $SD = 9.37$) did not differ, $p = .505$ (see Table 1 for a summary of infants' mean looking times at test events). Finally, there was a significant effect of age, $F(3, 88) = 2.91$, $p = .039$, $\eta^2_{partial} = .09$. Post hoc analyses indicated that 20-month-olds looked longer at test events ($M = 12.45$ s, $SD = 6.60$) than 10-month-olds ($M = 6.91$ s, $SD = 5.05$), $p = .045$. These data suggest that infants detected the category–trajectory violation which occurred in the jumping furniture event, but did not detect the category–trajectory violation which occurred in the rebounding animal event, mirroring the results of Experiment 1.

A second $2 \times 2 \times 4$ (Category $\times$ Motion $\times$ Age) analysis of infants' looking times at test events was conducted including data from participants who did not habituate; a similar pattern of results was found. A significant effect of motion was observed, with infants looking longer at jumping test events ($M = 11.38$ s, $SD = 8.10$) than at rebounding test events ($M = 8.97$ s, $SD = 6.07$; $F(1, 120) = 5.03$, $p = .027$, $\eta^2_{partial} = .04$). However, this effect was modified by a significant Category $\times$ Motion interaction ($F(1, 120) = 7.97$, $p = .006$, $\eta^2_{partial} = .06$) and by a trend for a Category $\times$ Motion $\times$ Age interaction ($F(3, 120) = 2.17$, $p = .095$, $\eta^2_{partial} = .05$). Post hoc analyses to the Category by Motion interaction revealed that infants looked longer at the jumping furniture events ($M = 12.46$ s, $SD = 9.73$) than the rebounding furniture events ($M = 7.97$ s, $SD = 6.46$) and that infants' looking times at the rebounding animal events ($M = 9.97$ s, $SD = 8.61$) and jumping animal events ($M = 10.29$ s, $SD = 9.25$) did not differ, $p < .001$ and $p = .804$, respectively. Considered together, these analyses indicate that infants who did and did not habituate detected the category–trajectory violation which occurred in the jumping furniture event and did not detect the category–trajectory violation which occurred in the rebounding animal event, mirroring the results of Experiment 1.

*3.3. Discussion*

In this second experiment, animals were contrasted with a typical category of inanimate object: furniture. Consistent with performance in Experiment 1, infants aged 10 months to 20 months looked longer at the jumping furniture than at rebounding furniture during the test phase; in contrast, infants' looking times at rebounding animals and jumping animals did not differ. These patterns indicate that infants responded to the jumping furniture event as more novel than the rebounding furniture event, but did not respond to the rebounding animal event as more novel than the jumping animal event. These results replicate the patterns found in Experiment 1 and provide support for the hypothesis that by 10 months of age infants can use motion properties of inanimate objects in their representations of this object kind.

## 4. General discussion

In two experiments, the infant-controlled habituation paradigm and switch design were used to assess 10–20-month-old infants' ability to associate motion paths (jumping and rebounding) with animals and inanimate objects (vehicles and furniture). In each experiment, 10–20-month-old infants were first habituated to two events. In one event an animal moved along a category-appropriate trajectory (jumping over a wall) and in the other event an inanimate object moved along a category-appropriate trajectory (rebounding off a wall). Infants then saw two test events, one that featured a category exemplar whose trajectory was consistent with its category membership (the congruent event) and another event that featured a category exemplar whose trajectory was inconsistent with its category membership (incongruent event). In Experiment 1, in which the inanimate objects were vehicles, infants as young as 10 months responded to jumping vehicles (an animate motion path) as more novel than rebounding vehicles (an inanimate motion path), suggesting that they had associated rebounding with vehicles. In contrast, infants as young as 10 months did not respond to rebounding by animals as more novel than jumping by animals. There are two possible interpretations of the latter results. One possibility is that infants did not detect the difference between jumping and rebounding animals. This interpretation seems unlikely given that infants responded differentially to vehicles, which followed the same jumping and rebounding motion paths. The second possibility is that infants perceived rebounding animals to be just as plausible as jumping animals. Indeed, animals do bump into obstacles. More broadly, the motion of animate beings is less constrained than the motion of inanimate objects, as the former is determined by both physical laws and agency whereas the latter is determined only by physical laws. Therefore, although one must be cautious when interpreting a null result, when considered in conjunction with infants' longer looking at jumping vehicles than at rebounding vehicles, infants' similar looking time at rebounding animals and jumping animals suggests that by 10 months of age, infants associate both motion paths with animals. In Experiment 2, we used a more salient animate–inanimate contrast (animals vs. furniture) and replicated and extended the findings of Experiment 1. That is, the same looking patterns were observed during the test phases when both animate and inanimate exemplars had moving parts (moving legs for animals and moving wheels for vehicles in Experiment 1) and when only the animate category had

moving parts (moving legs for animals and static legs for furniture in Experiment 2). In summary, the results of the present experiments indicate that by 10 months of age infants are able to associate the rebounding motion path with two types of inanimate objects (vehicles and furniture) and both the rebounding and jumping motion paths with animals.

Infants' ability to associate a motion path with vehicles observed in Experiment 1 partially replicates the results of a series of experiments using the generalized imitation procedure (Poulin-Dubois et al., 1999, 2006; Rakison, 2003) that found that 14-month-old infants associated miniature replicas of animals and vehicles with specific motion paths. For example, after observing an experimenter move a toy dog along a jumping path over a wall, infants chose another animal to imitate the action when offered a choice between doing so with a toy vehicle and a toy animal. In contrast, after observing the experimenter make a car roll up and down a ramp, they chose the vehicle to perform the same action. We replicated the results of the generalized imitation research in that infants responded to the animate motion path of jumping as more novel for vehicles than the inanimate motion path of rebounding, suggesting that they had associated the former path with vehicles. Our results differ from the inductive generalization research in that infants did not respond to the inanimate path of rebounding as more novel for animals than the animate path of jumping; thus our results differ from the inductive generalization research, which found that infants preferentially selected the animal to follow animate motion paths.

There are at least two possible explanations for the difference between the results for animals in research using the inductive generalization task and the results for animals in the present research using the infant-controlled habituation paradigm. One possible explanation, as mentioned earlier, is that infants' performance on the inductive generalization task could be influenced by seeing the experimenter manipulate the replica to demonstrate the action (e.g., use his/her hand to move the dog up and over a wall along a jumping path). Thus, during the demonstration the replicas are moved by an external force, which violates a key property of animate beings (Mandler, 2003). It is unclear how this category-violation might affect infants' subsequent imitation behaviour. A second possible explanation is that infants are required to do different things in the test phases of the inductive generalization task and the habituation task. In the inductive generalization task, infants are given a choice of two items and may choose one item with which to imitate a motion path. The item they select could be the one which they think is appropriate for the motion path, or it could be the one which they think is more appropriate for the motion path. In the habituation task used in the present research, infants were presented sequentially with two test events: One event depicted a vehicle (or piece of furniture) following a motion path and the other event depicted an animal following the same motion path; the motion path was appropriate for one category and inappropriate for the other category. The infant's task was to look at each sequentially presented event. We measured infants' looking time (level of interest) at each event and compared looking times at the two events. Due to the differences between the inductive generalization and habituation tasks, it is in some sense not surprising that different results were obtained. The present results also extend the results of research using the inductive generalization task to a second type of inanimate object (furniture) and downward in age, from 14 months to 10 months.

Research has demonstrated that infants consider animals, furniture, and vehicles to belong to distinct categories by 7 months of age (Mandler & McDonough, 1993, 1998a; Pauen, 2002a, 2002b) and that they discriminate between motion paths by 7–9 months (Pulverman et al., 2013). By 10 months of age, infants can categorize motion paths across changes in the specific manner in which the path is achieved (Pruden et al., 2013). The ability to categorize motion paths at 10 months is consistent with the findings of the present experiments. However, to date, no research had addressed infants' ability to associate motion paths with animals, vehicles, and furniture (but see Rakison, Cicchino, and Hahn's (2007) research using an inductive generalization task which demonstrated that 20-month-olds, but not 16-month-olds, understand that animals take a rational path towards a goal).

Kuhlmeier, Bloom, and Wynn (2004) found that 5-month-old infants treated one type of inanimate object (boxes) like material objects, but did not readily treat one type of animate being (humans) like material objects. Specifically, these researchers found that 5-month-old infants anticipated continuous motion of boxes, but erroneously did not also expect it of humans. In the present research, we tested infants' responses to category-specific motion paths and found that 10–20-month-old infants detected a violation in the motion path of vehicles and furniture (two other types of inanimate objects), but did not respond to such a change in the motion path of animals (another type of animate being). This suggests that by 10-months of age infants, like adults and older children, are more flexible concerning the motion of animals than the motion of these inanimate objects. Furthermore, infants' greater flexibility concerning the motion paths of animals relative to the motion paths of inanimate objects mirrors the more predictable nature of the motion by inanimate objects. Thus, the results of our research suggest a significant development in infants' understanding of animate beings and inanimate objects between the ages of 5 and 10 months.

In the present experiments, animals and vehicles differed in a number of ways, including causal and functional properties (moving legs vs. moving wheels) and overall appearance (curvilinear vs. rectilinear shape). The animals and furniture were also different in causal and functional properties (moving legs vs. static legs). It is unclear, therefore, whether the observed pattern of results is due to a priori categorical knowledge or due to online learning of associations between specific body parts (e.g., faces, legs, wheels) and two different paths of motion. The current design cannot directly tease apart these interpretations, nor was it designed to do so. Given the research on the role of perceptual features in categorization, it could be argued that these differences explain our results (Quinn, 2002). For example, one might argue that infants generalized the trajectory from one category exemplar to another one by correlating the legs with jumping and wheels with rebounding in Experiment 1. In Experiment 2, one could speculate that infants generalized the trajectory from one category exemplar to another by correlating the moving legs with jumping and stationary legs with rebounding. However, the probability

of infants' performance being due to a strictly online association between parts and motion path is lessened by the fact that (a) infants responded differently to the category-congruent and category-incongruent events for vehicles but not for animals, despite the fact that animals and vehicles had distinctive moving parts and distinctive trajectories; and (b) the same pattern was observed in infants' responses to vehicles and furniture—two types of inanimate objects—despite the fact that the former had moving parts and the latter had no moving parts. Regardless of whether the habituation phase played a role in infants' performance in the test phase, this research demonstrates that by 10 months of age infants are able to associate the inanimate rebounding motion path with inanimate objects and both the rebounding and animate jumping motion paths with animals. Whether these findings indicate that infants have already achieved the understanding that only animals are both psychological and physical "objects" remains an open question.

When considered together, the evidence from the present experiments is consistent with the view that infants' conceptual category of inanimate objects involves the ability to detect object motion (Mandler, 2000). We tested only one type of motion cue, namely motion path (smooth vs. irregular). Animals and vehicles differ in many other motion and causal properties, such as type of motion onset (self-propelled or caused) and type of causal role (agent or recipient), that have also been hypothesized to play a role in the early conceptualization of animals and vehicles (Rakison & Poulin-Dubois, 2001). The developmental sequence in which infants associate each of these motion properties to animates and inanimates remains to be charted. We predict that motion cues that can be analyzed by observing one object (e.g., trajectory, biological motion) will show developmental primacy over cues that require the coordination of two objects (e.g., contingency, causal role). For example, the category-specific nature of biomechanical and mechanical motion patterns seem to be acquired early, with infants as young as 9 months recognizing novel images of category members solely on the basis of the common motion characteristics of that category depicted in point-light displays (Arterberry & Bornstein, 2002).

To conclude, we believe that the present findings provide clear evidence that before the end of the first year infants are sensitive to the association between object kinds and the cue of motion path. They associated inanimate objects and the inanimate motion path of rebounding, but not the animate motion path of jumping. They associated both types of motion paths with animals. In effect, they restricted the animate motion path of jumping over an obstacle to animals. Infants' ability to associate motion path and object kind is consistent with the hypothesis that analysis of movement might play an important role in infants' global categories (Mandler, 2000). The mechanism or mechanisms by which children acquire and access this foundational knowledge remain to be identified.

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