

Find Your Manners: How Do Infants Detect the Invariant Manner of Motion in Dynamic Events?

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To learn motion verbs, infants must be sensitive to the specific event features lexicalized in their language. One event feature important for the acquisition of English motion verbs is the manner of motion. This article examines when and how infants detect manners of motion across variations in the figure's path. Experiment 1 shows that 13- to 15-month-olds ($N = 30$) can detect an invariant manner of motion when the figure's path changes. Experiment 2 reveals that reducing the complexity of the events, by dampening the figure's path, helps 10- to 12-month-olds ($N = 19$) detect the invariant manner. These findings suggest that: (a) infants notice event features lexicalized in English motion verbs, and (b) attention to manner can be promoted by reducing event complexity.

Central to understanding how children acquire motion verbs and spatial prepositions is an examination of how infants process, discriminate and categorize events, actions, and spatial relations. Infants must be able to make sense of the world of actions and events around them before they can map words onto these actions and events. Until recently, most investigations of children's developing verb lexicon have either explored children's production of motion verbs and spatial prepositions (Choi & Bowerman, 1991; Choi & Gopnik, 1995; Naigles, Hoff, & Vear, 2009; Tardif, 1996; Tomasello, 1992), or have explored the mapping of

motion verbs and spatial prepositions onto actions and events (Behrend, 1995; Choi, McDonough, Bowerman, & Mandler, 1999; Fisher, 2002; Maguire et al., 2010; Naigles, 1996). Research has only just begun to examine when and how infants have the conceptual knowledge and abilities needed to make sense of the events, actions, and spatial relations that motion verbs and other spatial words encode (see Göksun, Hirsh-Pasek, & Golinkoff, 2010; Golinkoff & Hirsh-Pasek, 2008; Pruden, Hirsh-Pasek, & Golinkoff, 2008; Wagner & Lakusta, 2009, for reviews). This article focuses on the knowledge children have before they map their first motion verbs onto actions and events (also see Hirsh-Pasek & Golinkoff, 2006).

Although most children produce their first motion verbs sometime before their second birthdays (Fenson et al., 1994; Naigles et al., 2009), we do not know when and how children acquire the conceptual knowledge needed to learn these verbs. Infants are quite proficient at representing the events they perceive in the world and do so at a

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relatively young age (see Pruden et al., 2008, for a review). For example, research demonstrates that infants can carve up larger events into individual units of action early in infancy (Baldwin, Baird, Saylor, & Clark, 2001; Bertenthal, Proffitt, & Cutting, 1984; Sharon & Wynn, 1998; Wynn, 1996). But, as Clark (2003) writes, infants also need “to know how to decompose scenes into the constituent parts relevant to linguistic expressions in the language” (p. 168). Motion verbs, for example, do not label whole actions; they label only a subset of actions called “semantic components.” These semantic components include *manner*, or the way in which a figure moves, (e.g., *walk*, *swagger*); *motion*, or the general fact that motion is taking place; *path*, or the trajectory of a figure with respect to a ground object, (e.g., *enter* the house); *figure*, or the primary agent or object in the event (e.g., *Charles* walked); *ground*, or the reference point to which the figure moves in relation (e.g., Charles circled *the barn*); *source*, or the beginning point of an event, and *goal*, the end point of an event (e.g., Charles walked from the *river* [source] to the *barn* [goal]; Jackendoff, 1983; Langacker, 1987; Talmy, 1985, 2000).

Within the class of motion verbs, specific subsets of these semantic components combine to generate the verb system in a language (Talmy, 1985; also see Langacker, 1987). For example, manner verbs, like *run*, *jump*, and *swagger*, encode the manner of motion. Verbs like *enter*, *approach*, and *ascend*, encode the path that the figure traverses. Some motion verbs encode more than one semantic component (Pulverman, Rohrbeck, Chen, and Ulrich, 2008). The motion verb *deplane*, for example, conveys information about both path and ground. Children must learn which semantic components are relevant to learning a particular verb in their native language and, importantly, must attend to and form categories of just those semantic components that jointly form that motion verb. Furthermore, they must learn the general tendencies in their language. English, for example, has more manner verbs than path verbs, while languages like Greek and Spanish are more likely to include path within the verb and manner outside of the verb, if at all, in an accompanying adverb (e.g., *ascendere*; Slobin, 2001; Talmy, 2000). Some argue that to learn verbs infants must be able to pay attention to and form categories of these semantic components before they can begin to map labels to them (Gentner & Boroditsky, 2001; Golinkoff et al., 2002). Thus, understanding how children learn verbs requires that we investigate when and how infants are able to make sense of those semantic compo-

nents conveyed by motion verbs. Here we explore whether English-learning infants abstract the *invariant* manner of motion from a set of dynamic events. More specifically, we examine (a) when infants can detect the manner of motion across variations in the path of the figure and (b) whether detection of the invariant manner of motion can be promoted in infants by reducing the relational complexity of the events.

Research suggests that infants both recognize changes to and form categories of semantic components encoded in both motion verbs and spatial prepositions. For example, infants notice containment and support relations, which are codified in English spatial prepositions (e.g., *in* and *on*). Baillargeon and colleagues (Baillargeon, 2004; Baillargeon & Wang, 2002; Hespos & Baillargeon, 2001a, 2001b; Hespos & Spelke, 2004) showed that 2.5-month-olds have a rudimentary understanding of what happens in both containment events (i.e., when something is lowered *into* an open container) and support events (i.e., when something is lowered *onto* a closed container). Furthermore, infants form categories of these events. By 6 months of age infants form categories of containment relations and by 14 months they form categories of support relations (see Casasola, 2008, for a review; Casasola, 2005; Casasola & Cohen, 2002; Casasola, Cohen, & Chiarello, 2003; McDonough, Choi, & Mandler, 2003). Finally, infants can represent both the sources and goals (Lakusta & Landau, 2005; Lakusta, Wagner, O’Hearn, & Landau, 2007; Wagner & Lakusta, 2009) and figures and grounds in dynamic motion events (Göksun, Hirsh-Pasek, & Golinkoff, 2009; also see Bornstein, Arterberry, & Mash, 2010, for infants’ categorization of figures across different contexts, or grounds, in static events).

Only a few studies have examined infants’ ability to discriminate changes in a figure’s path and manner of motion despite the importance of noticing these changes for learning motion verbs (Casasola, Hohenstein, & Naigles, 2003; Pruden, Roseberry, Göksun, Hirsh-Pasek, & Golinkoff, in press; Pulverman, Golinkoff, Hirsh-Pasek, & Sootsman Buresh, 2008; Pulverman, Song, Pruden, Golinkoff, & Hirsh-Pasek, in press). Pulverman, Golinkoff, et al. (2008), Pulverman, Rohrbeck, et al. (2008), and Pulverman et al. (in press) demonstrated that English- and Spanish-learning infants are able to discriminate among different paths and manners of action. Using a habituation paradigm, 7- to 9-month-olds and 14- to 17-month-olds were shown an animated starfish simultaneously performing a manner and path (e.g., starfish *spinning*

under [the ball]). After infants were habituated to this single event, they were shown four different test trials: a control trial in which infants viewed the same event as in habituation (e.g., starfish *spinning under* [the ball]), a path change trial (e.g., starfish *spinning over* [the ball]), a manner change trial (e.g., starfish *jumping jacks under* [the ball]), and a path and manner change trial (e.g., starfish *bending past* [the ball]). Both the younger and older infants increased their attention to all three of the path and manner change test trials, suggesting that they had discriminated changes in these two semantic components compared with the habituated event. Furthermore, infants also appear to discriminate paths and manners in dynamic events involving human agents (Casasola, Hohenstein, et al., 2003; also see Song, 2009).

Discrimination of path and manner changes, however, is not sufficient for learning motion verbs as motion verbs refer to *categories* of actions. Consider the action of "running." Infants must learn that similar and dissimilar actions are categorized together (as when both four-legged and two-legged animals run) and that even when other key features of the event change (such as the path, as in "running toward" or "running away"), the same manner of motion is still called *running*.

Previous research examined infants' ability to detect an invariant path when other features of the event, such as the figure's manner of motion, varied (Pruden et al., in press). Using a superset of the stimuli used by Pulverman, Golinkoff, et al. (2008), Pulverman, Rohrbeck, et al. (2008), and Pulverman et al. (in press), infants viewed an animated starfish performing four distinct *manners* across the same *path* during a familiarization phase (e.g., starfish *spinning over* [the ball], starfish *twisting over* [the ball], starfish *bending over* [the ball], and starfish *jumping jacks over* [the ball]). At test, infants were shown two events simultaneously: One event depicted a novel manner with the same path (e.g., starfish *toe touching over* [the ball]), and the other event depicted a novel manner with a novel path (e.g., starfish *toe touching under* [the ball]). Ten- to 12-month-olds showed a significant preference for the event containing the same path (i.e., familiar event) during the test phase, suggesting that they abstracted the invariant path across changing manners of motion. This study provided some of the first evidence that infants can detect invariant actions even when other key event features, such as the figure's manner of motion, were changing.

A second experiment tested the linguistic definition of path by showing that infants could only detect the invariant path across varying manners

when a ground object was present (Pruden et al., in press). That is, a *path* is present when there is an extrinsic relation between the figure and a ground object (Talmy, 1985). When the ground object (i.e., [the ball]) was omitted from the familiarization events, thereby removing the extrinsic path relation between the figure and ground object, infants no longer showed evidence of the ability to abstract the invariant relation. This study is further evidence that infants are in fact abstracting semantic components from dynamic events.

Little, however, is known about whether infants can abstract a figure's manner of motion when other features of the event—such as the figure's path—are in flux. As the majority of English motion verbs encode the manner of motion, this ability is fundamentally important to their acquisition. Herein, we examine when and how English-learning infants abstract the invariant manner of motion when the path of the figure is changing. Building off of Pulverman, Golinkoff, et al. (2008), Pulverman, Rohrbeck, et al. (2008), and Pulverman et al. (in press), and using a superset of the same animated stimuli, we explored when infants could abstract the manner of motion when the extrinsic relation of path between the figure and the ground object changed. Thus, infants participating in Experiment 1 were asked to extract the invariant *manner* of motion across situations in which the figure's *path* varied (e.g., starfish *spinning around* [the ball], starfish *spinning past* [the ball], etc.). We believe this ability is a core prerequisite to forming categories of these types of actions and events and thus is foundational to the acquisition of English motion verbs.

Experiment 1: When Can Infants Abstract the Invariant Manner of Motion Across Variations in Path in Dynamic Events?

Could 10- to 12-month-olds and 13- to 15-month-olds abstract the manner of motion across events varying the path of the figure? Research on infants' ability to abstract the path shows that infants aged 10–12 months can detect an invariant path when the figure's manner of motion changes (Pruden et al., in press). Thus, in the present experiment we began our investigation of infants' ability to abstract the invariant manner of motion with infants of the same age and using the same animated stimuli as had been used previously.

Infants viewed four exemplars of the animated character performing the same *manner* of motion across four different *paths*. Previous research by

Pulverman, Golinkoff, et al. (2008), Pulverman, Rohrbeck, et al. (2008), and Pulverman et al. (in press) shows that infants can discriminate changes in both path and manner using the same events we used in the familiarization phase of Experiment 1. During the test phase, infants were shown two test events simultaneously: one in which the animated character performed the same manner as before and the other in which it performed a novel manner. If infants are able to detect invariant manners of motion across changes in the figure's path, they should show a significant preference for one of the events over the other during the test phase. A significant preference demonstrates that infants can tell the difference between the familiarized manner and the novel manner and, importantly, provides some of the first evidence that infants can note changes in the manner of motion across other fluctuations in the event.

Method

Participants

Thirty 10- to 12-month-olds ($M = 11.36$, $SD = .78$; 15 males, 15 females) and thirty 13- to 15-month-olds ($M = 14.59$, $SD = .90$; 15 males, 15 females) formed the final sample. All infants were full term at birth and were recruited from monolingual, English-speaking households in suburban areas of Philadelphia, PA and Newark, DE. Most infants came from families with middle-class or upper-middle-class socioeconomic status and were Caucasian. Less than 5% of participants were of Hispanic, Asian American, or African American descent. An additional 15 infants across these two age groups were excluded from further analysis due to fussiness ($N = 12$), low attention ($N = 1$), and side bias ($N = 2$). Low attention was defined as watching less than 50% of the stimuli. Side bias was calculated by dividing infants' total looking to the right side of the screen by their total looking time to both the right and left sides of the screen (for all split-screen trials). Calculations greater than .80 or less than .20 were an indication of a bias for one side of the screen.

Stimuli

The stimuli were computer-animated dynamic motion events. No linguistic stimuli accompanied the events in either experiment. Each event consisted of a purple starfish character (roughly 6.75 in. width, from arm to arm and 5.25 in. in height, from head to toe) performing an action in relation to a stationary green ball (approximately 2.25 in.

wide and 2.00 in. tall) found in the center of the screen. This green ball served as the external reference around which the starfish moved. In each event, the animated starfish performed one of six manners (i.e., bending, bowing, jumping jacks, spinning, toe touching, and twisting; Figure 1) while moving along one of five different paths (i.e., over, under, past, around, and in front of; Figure 2). Combining the various *manners* and *paths* yielded a total of 30 possible events that infants could view (e.g., *bending over*, *bowing over*, etc.).

During each event, the animated starfish traversed a path while performing a manner over the course of 3 s. The starfish then reversed its direction and traversed back along the same path for an additional 3 s. The starfish repeated this pattern for a total of 12 s. One exception to this timing was the path, *around*. This path was traversed in 6 s with the starfish completing two continuous circles during the 12 s. Thus, the starfish moved at the same speed for the *around* path as it did for the *over* and *under* paths. These stimuli were based on those used in Pulverman, Golinkoff, et al. (2008), Pulverman, Rohrbeck, et al. (2008), Pulverman et al. (in press), and Pruden et al. (in press). The animated character and his actions were created using Strata 3Dpro™ version 3.9. Final editing of the digitized events was completed using Final Cut Pro HD™ version 4.5.

Procedure

The Preferential Looking Paradigm (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Hirsh-Pasek & Golinkoff, 1996), without language, was used. Infants participated in an introduction phase, a salience phase, a familiarization phase, and a test phase. Infants were seated on their parent's lap approximately 2.5 ft from a 44-in. television screen. Two video cameras, placed on either side of the television screen, were used to (a) record infant's eye gaze and (b) play the stimuli (Figure 3). Parents were asked to close their eyes and remain quiet during the study so that they could not influence their child's responses. Children's data would have been excluded from further analyses if their parents influenced their responses (e.g., parent pointed to events, parent turned their head to look at sides of screen, parent talked about events), but all parents complied.

Introduction phase. Infants first saw the animated character on one side of the screen for 6 s and then on the other side of the screen for another 6 s. During each of these 6-s events, the starfish moved across the screen from left to right and back while

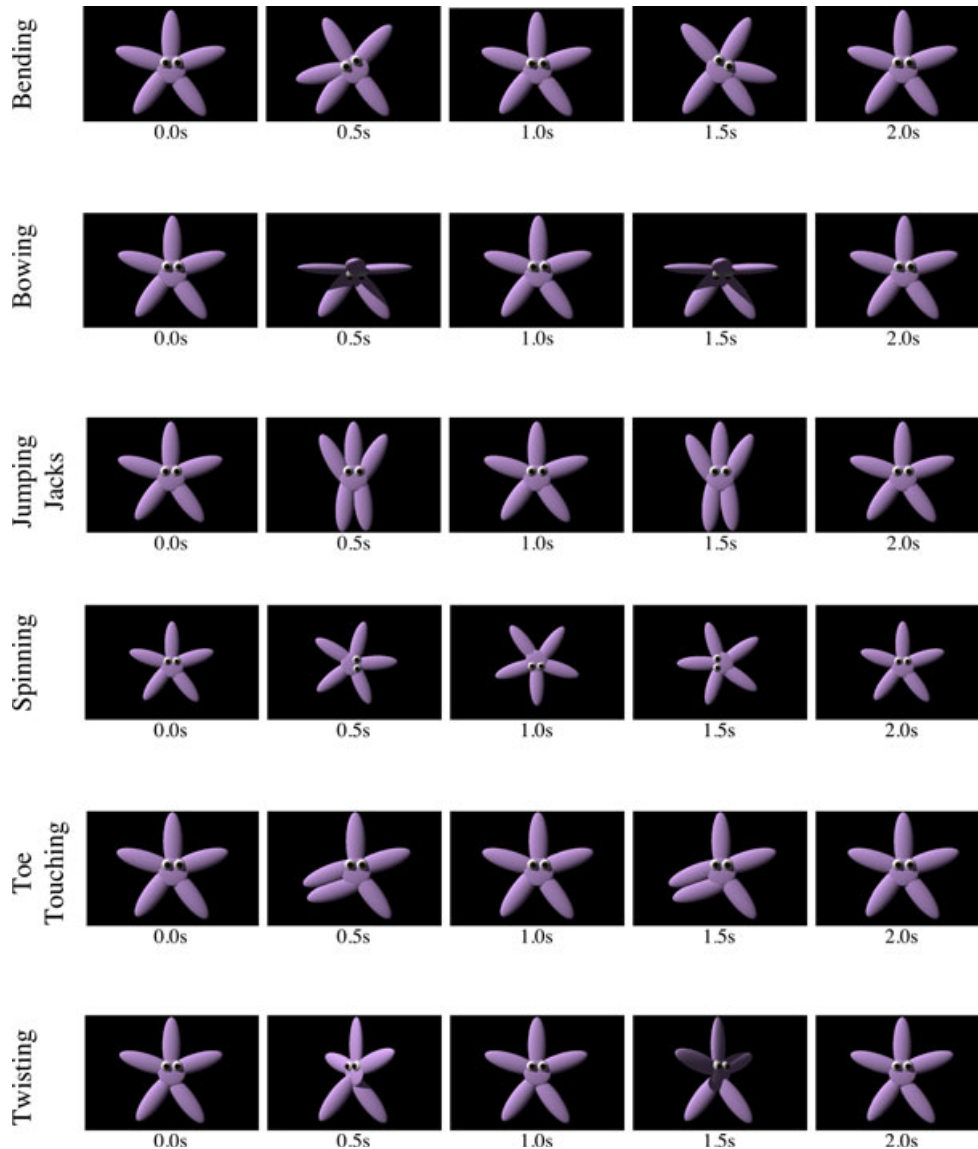


Figure 1. Six manners were created for the experiments. Each of the six manners are shown here as static pictures on a 2 s timescale, though they were presented as dynamic events.

stretching out his arms and legs. The ground object, the stationary green ball, was not present during the introduction phase events. The introduction phase was used to ensure that infants looked to both sides of the screen during the study (i.e., did not have a side bias). The order of appearance on each side of the screen was counterbalanced.

Saliency phase. The saliency phase presented events identical to those used during the test phase. Infants viewed two events side by side for a total of 12 s to measure any a priori preference for the test events.

Familiarization phase. Infants viewed four different 12-s events sequentially in the center of the

screen, yielding a total of 48 s of exposure across the familiarization phase. Each event was presented as a separate trial on the full television screen. Trials were separated by a centering stimulus. All four familiarization events were exemplars from the same manner category and shared a common *manner* but differed in their *path*. For example, infants in the manner condition, *spinning*, saw the starfish *spinning around* [the ball], *spinning past* [the ball], *spinning in front of* [the ball], and *spinning under* [the ball].

Test phase. The test phase assessed whether infants had detected a change in the manner of motion (in this example, *spinning*) across multiple exemplars of path. Infants were shown two events

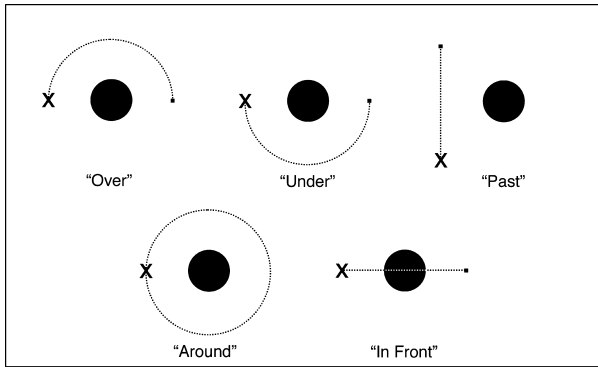


Figure 2. Five paths were created for the experiments. The X depicts the starting and ending points for each of the five paths, while the dotted line shows the path the figure followed.



Figure 3. The child sits on his or her parent's lap in front of a large television screen. A camera to the left of the television screen records the child's looking preferences to the visual stimuli, while a video camera to the right of the television screen plays the visual stimuli.

simultaneously on a split screen for 12 s. One was an *in-category*, familiar test event that contained the same *manner* seen during familiarization now com-

bined with a novel *path*. The other was an *out-of-category*, novel event with neither a *manner* nor a *path* seen during familiarization. For example, infants familiarized with the starfish *spinning around* [the ball], *spinning past* [the ball], *spinning in front of* [the ball], and *spinning under* [the ball] would, at test, see the starfish *spinning over* [the ball] (in-category test event—familiar *manner*, novel *path*) and *bending over* [the ball] (out-of-category test event—novel *manner*, novel *path*). Thus, in both test events, infants saw the same novel *path* (i.e., *over*), paired with either the familiar *manner* or new *manner*.

As with other studies evaluating infants' discrimination and categorization of spatial relations (e.g., McDonough et al., 2003), each 12-s test trial was repeated twice to ensure infants had ample time to view the test events. Twelve-second test trials allowed infants to see at least two repetitions of the figure's path. Infants were randomly assigned to one of six between-subject conditions, with each condition testing a different manner of motion (i.e., *bending*, *bowing*, *jumping jacks*, *spinning*, *toe touching*, and *twisting*). The side of the screen on which the familiar or in-category event appeared was counterbalanced across conditions.

Centering stimulus. A centering stimulus consisting of a 3-s video of a baby's smiling face accompanied by the song "Oh, Susanna," was used between trials to ensure that infants returned their gaze to the center of screen before each trial began.

Coding, reliability, and calculation of the dependent variable. The dependent variable was infants' visual fixation time to each event coded from video recordings by research assistants who were blind to the infant's familiarization condition. Buttons were depressed to record how long infants looked to the left, right, and center of the screen for each phase.

To calculate intercoder reliability, two independent coders coded 20% of the infants in both Experiments 1 and 2 with a resulting mean reliability of $r > .98$ ($SD \leq .01$). Intracoder reliability was calculated for 100% of the participants resulting in $r > .99$ ($SD \leq .01$) across both experiments.

A novelty-preference score was calculated for each child by taking the average looking time toward the out-of-category (novel) event and dividing by the sum of the average looking time toward the out-of-category (novel) event and the in-category (familiar) event. Proportions above .50 meant the infant looked at the out-of-category (novel) event longer than the in-category (familiar) event, while proportions below .50 meant the infant watched the in-category (familiar) event longer than the out-of-category (novel) event.

Results

Data sets for each age group were examined for suspected outliers (i.e., standardized z scores ≥ 2 SD). Data from four infants (two 10- to 12-month-olds and two 13- to 15-month-olds) were removed from their respective analyses because their salience phase data ($N = 1$) or test phase data ($N = 3$) were outliers.

The Salience Phase

No main effect of familiarization condition (i.e., *bending, bowing, jumping jacks, spinning, toe touching, twisting*), child gender, nor any interactions between these variables were found (for 10- to 12-month-olds, $F_s < 1.79$, $ps > .20$; for 13- to 15-month-olds, $F_s < 1.63$, $ps > .21$). Subsequent analyses collapsed across these variables. A planned contrast showed no difference in performance between the 10- to 12-month-olds ($M = 0.48$, $SD = .18$) and the 13- to 15-month-olds ($M = 0.49$, $SD = .20$), $t(57) = -0.29$, $p > .05$, $d = 0.08$, so we collapsed across age group. To evaluate whether infants had any a priori preferences for our test events we conducted a one-sample t test compared to a chance value of .50. This test revealed that infants did not show a preference for either event during the salience phase ($M = 0.49$, $SD = .19$), $t(58) = -0.51$, $p > .05$, $d = 0.13$, suggesting that infants found the test events equally salient prior to the familiarization phase.

The Familiarization Phase

Looking times during the familiarization phase were examined to determine whether there were any age differences in infants' attention to the events. A 2 (age group) \times 4 (familiarization trial) repeated measures analysis of variance (ANOVA) revealed a significant linear trend across the familiarization trials, $F(1, 58) = 19.09$, $p < .05$, $\eta_p^2 = .25$, but no main effect of age nor any interaction ($F_s < 0.46$, $ps > .71$). While infants across both age groups were equally attentive during the familiarization events, they did show a significant decline in looking across the familiarization trials (Figure 4, top graph).

The Test Phase: Finding the Invariant Manner in the Presence of a Ground Object

No main effect of familiarization condition, child gender, nor any interactions between these factors

(for 10- to 12-month-olds, $F_s < 1.25$, $ps > .33$; for 13- to 15-month-olds, $F_s < 2.19$, $ps > .16$) were found on the test phase data; thus, we collapsed across these factors. Children's novelty-preference scores at test were analyzed in a 2 (age group) \times 2 (test trial) mixed model ANOVA to assess age differences in the ability to abstract the invariant manner of motion across our two test trials. This analysis revealed a significant interaction between age group and test trial, $F(1, 54) = 7.27$, $p < .05$, $\eta_p^2 = .12$. This interaction was driven by a significant age difference for the second, $t(54) = 3.21$, $p < .05$, $d = 0.86$, but not first $t(55) = 0.10$, $p > .05$, $d = 0.03$, test trial.

We also wanted to know whether infants showed a significant preference for one event over

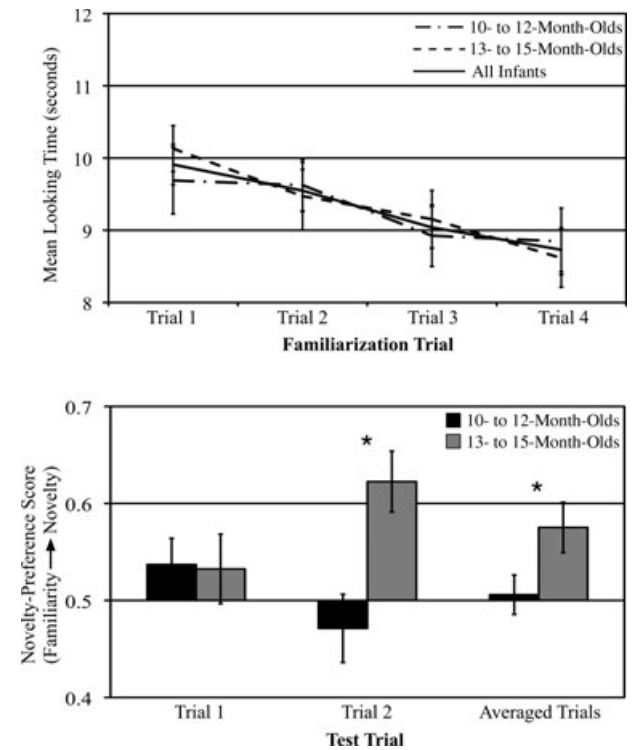


Figure 4. Top graph shows infants' looking times during the familiarization trials for Experiment 1. The y axis shows average looking time in seconds (of 12 s). Infants in both age groups showed a linear decline in their looking times during the familiarization phase, however, infants from the two age groups did not differ in their attention to the familiarization events. The bottom graph displays infants' looking times during test trials for Experiment 1. The y axis depicts the average novelty-preference scores. A number greater than .50 indicates a preference for the novel event, while a number below .50 indicates a preference for the familiar event. Only the 13- to 15-month-olds showed a significant preference for the out-of-category test event. * $p < .05$.

the other within the test trial that showed age differences (i.e., the second test trial) and averaged across our two test trials. One-sample t tests found that 10- to 12-month-olds showed no significant preference for either event during the second test trial ($M = 0.47$, $SD = .18$), $t(26) = -0.82$, $p > .05$, $d = 0.32$, or across the averaged test trials ($M = 0.51$, $SD = .11$), $t(27) = 0.29$, $p > .05$, $d = 0.11$. However, 13- to 15-month-olds showed a significant preference for the out-of-category (novel) event during the second test trial ($M = 0.62$, $SD = .17$), $t(28) = 3.90$, $p < .05$, $d = 1.48$, and across the averaged test trials ($M = 0.58$, $SD = .14$), $t(28) = 2.90$, $p < .05$, $d = 1.09$. Figure 4 (bottom graph) depicts infants' average looking times for both age groups, both broken down by test trial and averaged across test trials.

Discussion

Experiment 1 investigated when English-learning infants could abstract the invariant manner of motion, a component lexicalized in English motion verbs, across changes in the figure's path. Two groups of infants, 10- to 12-month-olds and 13- to 15-month-olds, were tested on their ability to detect the invariant manner of motion across variations in the figure's path. The main result of this study was that 13- to 15-month-old infants abstracted the invariant manner of motion by showing a significant preference for the novel, out-of-category event during the test phase. The 10- to 12-month-olds infants, on the other hand, failed to show a significant preference for either event during either test phase, suggesting that they could not abstract the invariant manner of motion. This finding was driven by an interaction between age group and test trial, which showed that 13- to 15-month-olds performed differently than the 10- to 12-month-olds during the second test trial.

Importantly, there was no a priori preference to our test events prior to the familiarization phase, indicating that any observed differences between test events were not the result of children's initial preference for one event over another in a pair. Rather, we can infer that a preference for one of our events at test resulted from viewing the varied familiarization events and abstracting the invariant manner of motion.

Analysis of the familiarization phase data revealed that infants showed a significant and reliable decrement in looking across the familiarization trials. A reliable decrement in looking to familiarization stimuli has been taken as evidence that

infants engaged in categorization of the spatial relations above, below and between in previous research (Quinn, 1994, 2003; Quinn, Adams, Kennedy, Shettler, & Wasnik, 2003). The reliable decrement in looking time seen here suggests that infants noticed the common manner of motion in each familiarization event, and perhaps were even engaged in a form of categorical processing. Furthermore, the fact that infants younger than 10 months have the ability to discriminate between the same events used in the present study (Pulverman, Golinkoff, et al. 2008; Pulverman, Rohrbeck, et al. 2008), suggests that success in the present study is not due to infants' failure to discriminate between our familiarization events. Taken together, these findings suggest that before infants begin to produce their first verbs they have the ability, at 13–15 months, to detect the invariant manner of motion over changing paths. Our youngest group of infants, however, did not show evidence of this ability.

Why might the youngest infants fail to show evidence of this ability? Even young infants have some rudimentary abilities to abstract and categorize those components encoded in other types of spatial terms, including those lexicalized in spatial prepositions (Casasola, 2005; Casasola & Cohen, 2002; Casasola, Cohen, et al., 2003; Casasola, Hohenstein, et al., 2003; Göksun et al., 2009; Lakusta & Landau, 2005; Lakusta et al., 2007; Pruden et al., in press; Pulverman, Golinkoff, et al. 2008; Pulverman, Rohrbeck, et al. 2008; Pulverman et al., in press). In research investigating the discrimination of manner and path, 7- to 9-month-olds discriminated changes to a figure's manner of motion (using a set of the very same stimuli) after repeatedly viewing one single exemplar performing a manner/path combination (Pulverman, Golinkoff, et al., 2008; Pulverman, Rohrbeck, et al., 2008; Pulverman et al., in press). In the present study, infants viewed four *different* exemplars, each one depicting the same manner across varying paths, and were asked to discriminate among changes in manner across multiple exemplars. Only the oldest infants, the 13- to 15-month-olds, provided reliable evidence of the ability to abstract the figure's manner of motion. Perhaps, then, abstracting an invariant action across several different dynamic events is just too difficult for infants younger than 13 months. Our previous research on infants' ability to detect an invariant path across changing manners suggests otherwise. Infants younger than 13 months show evidence of the ability to abstract an invariant path across changes in the figure's manner of motion (Pruden et al., in press).

While infants do show the ability to form some dynamic event categories before their first birthdays, it may be that some semantic components are easier to represent and detect than others. Recent neuro-imaging work suggests that different brain regions are sensitive to changes in path and manner (Wu, Morganti, & Chatterjee, 2008) and may follow different maturational timelines (Chatterjee, 2008). This may be why we see 10- to 12-month-olds detect changes in path (Pruden et al., in press), but not manner. Indeed, existing research shows that infants discriminate and/or categorize containment before support relations, goals before sources, and figures before grounds (Casasola & Cohen, 2002; Göksun et al., 2009; Lakusta et al., 2007). This apparent *décalage* in the abstraction of semantic components may simply be a reflection of the perceptual saliency of some of these components. For example, the goals of events appear to draw more attention than the sources (Lakusta & Landau, 2005; Regier & Zheng, 2007). Similarly, paths may simply be more salient and draw more attention than manner. Or perhaps children extract those components earlier that are more likely to be expressed frequently in the languages of the world. Finally, some suggest that the semantic components labeled by motion verbs and spatial prepositions may be built from "conceptual primitives" (Mandler, 1991, 1992, 2004). According to Mandler (2004), infants start life with a set of privileged concepts used to make sense of events in the world and then to package these events for language. The semantic component, *path*, is thought to be one of these privileged concepts, while *manner* is not. Knowing where you are going (i.e., path) may be more important than knowing how you got there (i.e., manner). In fact, research suggests that young infants rely on spatiotemporal information, in the form of locations and paths, to determine an object's identity, even in the face of other relevant cues (i.e., object property or kind information; Xu & Carey, 1996). Thus, it may simply be the case that abstracting the figure's path is easier than abstracting the figure's manner of motion.

Another explanation for why our youngest infants failed to show the ability to abstract the invariant manner of motion is that we made the task of locating the invariant manner of motion more difficult by varying other event components that encode relational information, in this case, the path of the figure. Perhaps then the diversity of the paths across our familiarization events was intriguing to the 10- to 12-month-olds causing them to pay less attention to the figure's manner of motion. If

this is the case, then younger infants might succeed at abstracting the figure's manner of motion under conditions in which the manner of motion is made more salient, while other relational information such as the path is reduced or removed. We explore this question in Experiment 2 by examining whether our youngest age group, the 10- to 12-month-olds, can abstract the figure's manner of motion when additional relational information is removed. In Experiment 1, a green ball in the center of the screen served as the external referent against which the path of the figure's movement was defined. In Experiment 2, we examine whether removing this ground object reduces the external path relation making the figure's manner of motion more salient.

Experiment 2: Does Reducing Extrinsic Relational Information Help 10- to 12-Month-Olds Abstract the Invariant Manner of Motion?

Experiment 2 tests whether 10- to 12-month-olds can abstract the invariant manner of motion under conditions in which other external relational information, here path information, is dampened. In Experiment 1, infants were presented with complex, dynamic events that included both a manner intrinsic to the figure paired with extrinsic path information. In these events, the starfish performed the same manner of motion paired with four different paths. Thirteen-month-olds and older infants showed evidence of the ability to abstract the invariant manner of motion across these varying paths. One possibility for why the youngest infants tested did not show evidence of this ability is that they were busy attending to the highly salient relational information between the figure and the ground object (i.e., the path changes) and, thus, not focusing their attention to the invariant manner of motion.

In real-world events, a figure performing a manner need not always do so with reference to a ground object. For example, when a child watches Mommy dance, Mommy is not moving with respect to any of the objects in the room. Thus, a manner of motion can be performed against a backdrop of objects and enclosures without creating a relation with a specific ground object. In Experiment 1, we created the analog of Mommy (i.e., the animated starfish) dancing with relation to a chair (i.e., the green ball). What would happen to the perception of manner if the chair or in our case, the green ball, were removed? Would infants now

show the ability to abstract the figure's manner of motion? Here, we examined whether removing the ground object reduces the salient path information and helps infants focus their attention on the manner of motion resulting in the abstraction of the invariant manner of motion.

In Experiment 2, we omitted the central ground object (i.e., the green ball), thereby reducing the extrinsic relational information and allowing the manner to stand out on its own. While there exists the possibility that some extrinsic relational information may still exist after the removal of the ground object, (e.g., there is some extrinsic relational information to be gleaned from the trajectory of the figure in relation to the screen of the television), we believe that removing the ground object significantly *reduces* extrinsic relational information. We hypothesized that without the green ball, infants would no longer need to process the relation between the manner and the path the figure traversed with respect to the ground object. As manner is an intrinsic movement of the figure and does not require an external ground object, reducing the relational information between the figure and the ground might enhance the detection of the invariant manner.

Method

Participants

Nineteen 10- to 12-month-olds ($M = 11.42$, $SD = .73$; 11 males, 8 females) made up the final sample for Experiment 2. Only 10- to 12-month-olds were included, as older infants already revealed the ability to abstract the invariant manner of motion. Five additional 10- to 12-month-olds were excluded from further analysis because of fussiness ($N = 2$), side bias ($N = 2$), and experimenter error ($N = 1$).

Stimuli, Procedure, and Coding

Stimuli were identical to those in Experiment 1, with one key change. The dominant ground object, the green ball, was removed from all events shown during Experiment 2, including the events shown during the salience, familiarization, and test phases. The procedure and coding for Experiment 2 were identical to Experiment 1.

Results

Data were examined for suspected outliers (i.e., standardized z scores $\geq 2 SD$). Data from two

infants were removed from their respective analyses because their salience ($N = 1$) or test phase data ($N = 1$) were outliers.

The Salience Phase

No main effects of familiarization condition, child gender, or any interaction between these variables were found on the salience phase data ($F_s < 1.15$, $ps > .41$). Further analyses collapsed across these variables. To evaluate infants' a priori preferences for our test events a one-sample t test, compared to a chance value of .50, was conducted and revealed that infants did not show a preference for either event ($M = 0.50$, $SD = .14$), $t(17) = 0.13$, $p > .05$, $d = 0.06$. These analyses suggest infants did not have any a priori preference for our test events prior to the familiarization phase.

The Familiarization Phase

A repeated measures ANOVA using the familiarization data showed a significant linear trend, $F(1, 18) = 4.55$, $p < .05$, $\eta_p^2 = .20$ (Figure 5; top graph), suggesting that infants had habituated to the familiarization stimuli.

The Test Phase: Finding the Invariant Manner in the Absence of a Ground Object

Preliminary analyses on the test phase data indicated no effects of familiarization condition or child gender, nor any interactions between these factors ($F_s < 2.86$, $ps > .14$). Further analyses collapsed across these variables. A paired-samples t test on infants' looking preferences from the two test trials showed that infants' looking preferences from first test trial ($M = 0.57$, $SD = .14$) did not significantly differ from that of the second test trial ($M = 0.62$, $SD = .22$), $t(17) = 0.95$, $p > .05$, $d = 0.28$. Next, we examined whether removing the dominant ground object made the manner of action more salient to infants, allowing them to abstract the invariant manner of motion. To examine whether infants had a significant preference for either event during the test phase, a one-sample t test was conducted on the novelty-preference scores collapsed across the two test trials. This test revealed that infants showed a significant preference for the novel, out-of-category event during the test phase ($M = 0.60$, $SD = .15$), $t(17) = 2.90$, $p < .05$, $d = 1.41$.

Finally, a post hoc contrast of those infants participating in Experiment 2 to those 10- to 12-month-

olds participating in Experiment 1 was conducted to determine whether infants in these two studies were performing differently. An independent-samples *t* test revealed that the group of infants in Experiment 2 significantly differed in their novelty-looking preferences when compared with those of the same age in Experiment 1, $t(44) = 2.56, p < .05, d = 0.74$. Figure 5 (bottom graph) shows infants' looking times during the test phase for 10- to 12-month-olds in both Experiments 1 and 2.

Discussion

In Experiment 2, we dampened extrinsic relational information by removing the ground object against which the starfish moved. The question we raised was when *path* information is reduced, would infants be more likely to pay attention to and ultimately abstract the figure's manner of motion? If

infants have difficulty processing relational information, then removal of the dominant ground object, the green ball, should not only reduce the relational complexity of the event but also increase the salience of the manner of motion. Results showed that removal of the dominant ground object did help 10- to 12-month-olds abstract the invariant manner. Ten- to 12-month-old infants now showed a significance preference for the novel, out-of-category event during the test phase. Furthermore, our results indicated that the test phase looking times from the infants participating in Experiment 2 were significantly different from those 10- to 12-month-olds in Experiment 1.

We now have evidence that infants younger than 12 months abstract the invariant manner of motion, but do so under limited conditions. Why were the infants unable to show evidence of this ability when the dominant ground object *was* present? One possibility is that infants did not notice the manner of motion because they were paying more attention to the extrinsic path relation between the figure and the ground object. If, as Mandler (2004) suggested, path is a "conceptual primitive" required for learning about the dynamic world, then infants may simply be more attuned to the figure's path than to the figure's manner.

Dampening this extrinsic relation, by removing the dominant ground object, should both reduce attention to the path, as it theoretically no longer exists, and likewise, increase attention to the manner. Indeed, the present research and our previous research on infants' abstraction of the invariant path suggest that this is exactly what happens: Infants are no longer able to abstract the invariant path (Pruden et al., in press), but are able to abstract the invariant manner when extrinsic relational information is dampened.

Yet another possibility is that infants simply had too much visual information to process given that the events contained a figure, a ground object, a path, and a manner. Removing the ground object, not only eliminated the path relation but also reduced the amount of visual information infants needed to process to be successful in making sense of the events. However, this explanation seems unlikely given previous research (Pruden et al., in press) on infants' ability to abstract the invariant *path* across changing manners of motion. When the ground object was removed in that study, infants no longer detected the invariant path. Thus, it is unlikely that the successful performance of infants in our second experiment is the result of merely a reduction of the amount of visual information. When

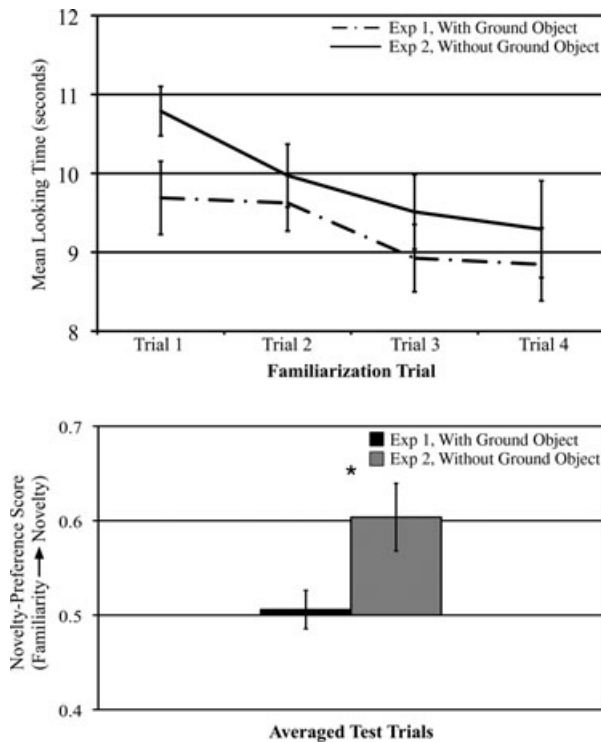


Figure 5. Top graph depicts infants' looking times during the familiarization trials for 10- to 12-month-olds in Experiment 1 and Experiment 2. The y axis shows average looking time in seconds. The bottom graphs reveals infants' looking times during test trials for those 10- to 12-month-old infants' participating in Experiment 1 and those infants participating in Experiment 2. The y-axis depicts the average novelty-preference scores. Infants participating in Experiment 2, in which the ground object was removed, looked longer at the novel, out-of-category event during the test phase.

* $p < .05$.

reduced visual complexity corresponds to reduced *conceptual* complexity—as in the present study—then infants can apparently detect the invariant component in question, the manner of motion.

General Discussion

The research presented here begins to illuminate when and how infants abstract the invariant manner of motion in nonlinguistic, dynamic events. Manner is an *intrinsic* movement determined by the properties of the figure rather than an *extrinsic* relation between the figure and the ground object. The manner of motion, the way in which a figure moves, is a semantic component encoded in verbs across many languages of the world. For example, English uses a great number of motion verbs that incorporate the manner of motion (e.g., *skipping*, *hopping*). In two experiments, we provided some of the first evidence that infants can detect changes in the type of information found in dynamic events. Experiment 1 revealed that 13- to 15-month-olds could abstract the invariant manner across variations in the figure's path. Younger infants, 10- to 12-month-olds, did not show evidence of having this ability. Yet, when in Experiment 2, the dominant ground object was omitted, thereby reducing the relational complexity of the event, and incidentally increasing the salience of the manner of motion, these infants were now able to abstract the invariant manner of motion. These findings, along with Pulverman, Golinkoff, et al. (2008) and Pulverman, Rohrbeck, et al. (2008) study that demonstrated 7-month-olds could discriminate changes in single paths and single manners, suggest that infants under 1 year of age can discriminate between manners of motion in dynamic events. The present studies also extend Pulverman and colleagues' findings to show that 13- to 15-month-olds could detect changes in an invariant manner across changes in the figure's path. However, the 10- to 12-month-olds in the present study only showed success in detecting the invariant manner under very limited conditions, namely, a condition in which the extrinsic path relation between the figure and the dominant ground object was deemphasized.

The current findings, along with our previous research showing that infants can abstract the invariant path across variations in the figure's manner of motion by 10–12 months (Pruden et al., in press), provide additional support for the idea that infants are capable of paying attention to semantic components encoded in spatial prepositions and motion

verbs. Furthermore, the ability to abstract the invariant actions in the face of other changes in the event suggests that infants may be capable of forming categories of these actions and semantic components. Future work will need to explore these categorization abilities by asking whether infants can generalize these invariant semantic components to other agents performing them and to perceptually dissimilar exemplars of the category (e.g., cats running, humans running, cheetahs running).

The present research and that on other semantic components lexicalized in spatial terms, including containment, support, source, goal, figure, and ground (Casasola, 2005; Casasola & Cohen, 2002; Casasola, Cohen, et al., 2003; Casasola, Hohenstein, et al., 2003; Göksun et al., 2009; Lakusta & Landau, 2005; Lakusta et al., 2007; Pruden et al., in press; Pulverman, Golinkoff, et al. 2008; Pulverman, Rohrbeck, et al., 2008; Pulverman et al., in press), suggest that infants are equipped with those abilities needed to make sense of the events in their world. That is, infants have the capabilities to both pay attention to and form categories of actions and events. These two skills play a critical role in children's acquisition of relational language (Parish-Morris, Pruden, Ma, Hirsh-Pasek, & Golinkoff, 2010). Children would be unable to map language they hear to events they witness without the fundamental ability to detect the semantic elements that will be packaged in the motion verbs of their language.

Since this research is among the first to examine how infants abstract invariant components of dynamic motion events (also see Pruden et al., in press), it leaves us with many unanswered questions. Research has begun to investigate young infants' *discrimination* of other event components in dynamic motion events, such as figure and ground (Göksun et al., 2009), and source and goal (Lakusta et al., 2007), yet no research has explored infants' detection and categorization of these components within dynamic events. Infants can form categories of these types of event components within the context of static events. For example, Bornstein et al. (2010) find that 6-month-olds can form categories of figures across different external contexts, or grounds, in static photographs. But when and how do infants form categories of figure, ground, source, and goal in the flow of dynamic events? Do each of these semantic components develop on the same timeline, or are some more privileged than others in development? What also remains a mystery is how children's early linguistic environment influences both the order and developmental timeline in which children acquire the ability to make sense of events. Do chil-

dren raised in cultures in which the language emphasizes the path, rather than manner of motion, in verbs (e.g., Spanish) follow the same developmental trajectory as seen in English-learning infants? Should cross-linguistic research find that infants from different languages do not vary in these early abilities then perhaps infants are equipped to make sense of a world of relations, even those relations not lexicalized in their ambient language. Such evidence would suggest that children's early event categories might initially be universal. However, as children receive more exposure to their native language, they may become more sensitive to some aspects of events than others, resulting in the kinds of semantic distinctions seen in older children and adults (Göksun et al., 2010).

Another promising line of inquiry comes from recent research in infant speech perception that suggests a link between infants' perceptual abilities and their later language skills (Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005; Newman, Ratner, Jusczyk, Jusczyk, & Dow, 2006; Tsao, Liu, & Kuhl, 2004). Kuhl and colleagues demonstrated a relation between early phonological discrimination and later language learning. English-reared 7-month-olds who were better at discriminating between native and nonnative contrasts had better language abilities at 30 months of age. This effect extended beyond vocabulary, with infants not only showing larger productive vocabularies but also showing longer mean length of utterance, and increased sentence complexity. Other research suggests that there are wide individual differences in the amount of spatial language children produce (Pruden & Levine, 2011) and that these differences may actually predict later cognitive functioning, including children's later spatial skills (Pruden et al., 2011). These findings suggest that it may be fruitful for future research to examine the possible link between infants' ability to find the semantic components in events and children's later production of spatial terms. Individual differences in detecting and categorizing relational information, including the abstraction of common manners and paths, may actually predict children's later verb and preposition use. The uncovering of such relations might have important implications for language delay and disorder.

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