Journal of Experimental Child Psychology 151 (2016) 77–95

Contents lists available at ScienceDirect

Journal of Experimental Child Psychology

journal homepage: www.elsevier.com/locate/jecp

Prelinguistic foundations of verb learning: Infants discriminate and categorize dynamic human actions

Lulu Song [a,*], Shannon M. Pruden [b], Roberta Michnick Golinkoff [c], Kathy Hirsh-Pasek [d]

[a] Brooklyn College, The City University of New York, Brooklyn, NY 11210, USA
[b] Florida International University, Miami, FL 33199, USA
[c] University of Delaware, Newark, DE 19716, USA
[d] Temple University, Philadelphia, PA 19122, USA

ARTICLE INFO

Article history:
Available online 9 March 2016

Keywords:
Categorization
Discrimination
Human actions
Verb learning
Event perception
Preferential looking paradigm

ABSTRACT

Action categorization is necessary for human cognition and is foundational to learning verbs, which label categories of actions and events. In two studies using a nonlinguistic preferential looking paradigm, 10- to 12-month-old English-learning infants were tested on their ability to discriminate and categorize a dynamic human manner of motion (i.e., way in which a figure moves; e.g., *marching*). Study 1 results reveal that infants can discriminate a change in path and actor across instances of the same manner of motion. Study 2 results suggest that infants categorize the manner of motion for dynamic human events even under conditions in which other components of the event change, including the actor's path and the actor. Together, these two studies extend prior research on infant action categorization of animated motion events by providing evidence that infants can categorize dynamic human actions, a skill foundational to the learning of motion verbs.

* Corresponding author.
E-mail address: lsong@brooklyn.cuny.edu (L. Song).

http://dx.doi.org/10.1016/j.jecp.2016.01.004
0022-0965/

Introduction

Skilled processing of actions and events is a critical cognitive achievement. It not only supports infants' understanding of physical laws (i.e., object solidity and permanence; Baillargeon, 2004) and people's goals (Woodward, 1998) but also serves as a foundation for linguistic communication (Baldwin, Andersson, Saffran, & Meyer, 2008; Golinkoff & Hirsh-Pasek, 2006; Nelson, 1986). Because actions and events are often encoded in language by *verbs*, the processing of actions and events is a fundamental task for verb learning (Gentner & Boroditsky, 2001; Golinkoff & Hirsh-Pasek, 2008; Golinkoff et al., 2002). Although significant progress has been made in understanding how infants process actions and events (e.g., Baldwin, Baird, Saylor, & Clark, 2001; Baldwin et al., 2008; Hirsh-Pasek & Golinkoff, 2006), only a handful of studies have documented infants' categorization of actions and events that are eventually lexicalized in verbs (e.g., Pruden, Göksun, Roseberry, Hirsh-Pasek, & Golinkoff, 2012; Pruden, Roseberry, Göksun, Hirsh-Pasek, & Golinkoff, 2013). The current article adds to this literature by demonstrating under what conditions English-learning prelinguistic infants discriminate and categorize the kinds of complex human actions that are typically captured in motion verbs. More specifically, we examined 10- to 12-month-olds' ability to discriminate and categorize intransitive human actions (i.e., *marching*) across a variety of actors and paths (i.e., actors' trajectory).

Forming categories of objects, actions, and events is important for word learning because words (other than proper nouns) refer to categories of instances (Gentner & Boroditsky, 2001; Markman, 1991; Oakes & Rakison, 2003; Waxman, 2003). Categorization is the ability to classify or group discriminable objects, people, properties, relations, or events into classes and to respond to their class membership or commonalities rather than their uniqueness (Bruner, Goodnow, & Austin, 1956). Similarly, Murphy (2010) defined a category as "a set of things that are treated equivalently in one or another respect. . .. Instances from the same category are treated equivalently because they tend to share groups of attributes that make the category instances similar to one another" (p. 11). Critically, categorization differs from discrimination "in that more than two distinctive properties, objects, or events are involved. For example, categorizing animals involves finding properties in common but differences between the animals and various vehicles. Discriminating occurs when a single dog is treated as different from a single cat" (Oakes & Rakison, 2003, p. 3). Categories of actions and events, labeled by motion verbs and spatial prepositions, are formed when infants treat discriminably different action exemplars equivalently. Consider the English motion verb *jump*. When performed by people that vary in physical characteristics such as weight, height, muscle strength, and flexibility, the action of jumping can look drastically different. Even when performed by the same person, jumping can appear different from one instance to another depending on location and purpose (e.g., a person can jump off the chair, up the stairs, or over the ditch). Furthermore, humans can jump, animals can jump, and even inanimate objects can jump (e.g., when the alarm clock jumps off the table). In all cases—and despite perceptual differences in the actions—English speakers refer to these category exemplars with the same motion verb, *jump*. Thus, infants' categorization of actions hinges on their ability to perceive both the commonality and uniqueness of action exemplars. With this categorical representation in place, children can identify and map labels to novel action exemplars. Forming a categorical representation of an action across multiple exemplars is the basis for verb mapping and extension (Golinkoff & Hirsh-Pasek, 2006; Golinkoff et al., 2002).

Although language is categorical and the expert language user (i.e., adult) tends to describe categories in linguistic terms, forming categories of action *may precede* the emergence of linguistic labels in infants (Quinn, 2007), as it does in deaf children who have no formal language system (Goldin-Meadow & Zheng, 1998; Zheng & Goldin-Meadow, 2002). Theoretically, some have suggested that prelinguistic infants might be equipped with "image schemas" (e.g., path, containment, up–down, link) that represent dynamic spatial relations prior to language learning (Mandler, 1992, 2004; Mandler & Cánovas, 2014). Others hypothesize that the ability to perceive and process events and spatial relations might be in place in prelinguistic infants without making a commitment about the form these representations take (Gentner, 1982; Snedeker & Gleitman, 2004). Only a handful of studies have systematically examined when and how infants categorize actions and events that are labeled by English motion verbs (see Pruden et al., 2012, 2013, for work with animated actions), with these

studies generally finding that infants categorize nonlinguistic actions and events between 10 and 15 months. Notably, these are the same ages when infants begin to show comprehension of action words. The earliest English action words appear in children's receptive vocabularies toward the end of the first year (e.g., *kiss* appears at ~10 months, *hug* appears at ~12 months; Fenson et al., 1994). Given infants' knowledge of these action words, we anticipate that infants will be able to categorize at least some human actions and events before their first birthday.

Before infants can form categories of actions, infants must first parse events into individual actions. Because actions and events do not unfold in a discrete manner, the ability to individuate actions from a continuous stream of motion is requisite to forming action categories. Research suggests that prelinguistic infants have this ability. For example, in one study 10-month-olds were familiarized with a video clip that showed a woman noticing a towel on the kitchen floor, bending down to pick it up, and placing it on a towel rack with no obvious break between actions (Baldwin et al., 2001). At test, infants showed renewed attention when a still frame was inserted within the boundaries of the action (i.e., before the woman grasped the towel) but remained bored when the still frame appeared between two discrete actions (i.e., after the woman grasped the towel but before she stood up and moved toward the towel rack), suggesting that infants can parse a continuous stream of actions into its constituent parts. Similarly, younger infants, 6- and 8-month-olds, can detect a salient target action in a continuous action sequence (Hespos, Saylor, & Grossman, 2009). There is also evidence that 7- to 9-month-olds can segment continuous events using transitional probabilities (Roseberry, Richie, Hirsh-Pasek, Golinkoff, & Shipley, 2011; Stahl, Romberg, Roseberry, Golinkoff, & Hirsh-Pasek, 2014). Furthermore, studies show that salient action effects help to parse continuous action into individual actions for 9- to 12-month-olds (Elsner, Hauf, & Aschersleben, 2007; Verschoor, Paulus, Spape, Biro, & Hommel, 2015). Thus, within the first year of life and often before the onset of receptive language, infants are capable of breaking continuous action streams into discrete units. However, the question that remains is whether infants can group these distinct units of action into action categories that are typically lexicalized in motion verbs and other relational terms.

Linguistic theories may offer a useful perspective for investigating infants' categorization of dynamic human actions and events (Jackendoff, 1983; Langacker, 1987; Talmy, 1985). Talmy (1985) proposed that the linguistic representation of motion events includes several key components, including manner (i.e., way in which an action or motion is carried out by a figure; e.g., *marching* vs. *hopping*) and path (i.e., trajectory of a figure with respect to a reference point; e.g., *down the stairs*), among others. Languages typically lexicalize manner and path as predicates via verbs or prepositions (Talmy, 1985). Thus, to understand the foundation for verb learning, we need to examine whether infants process components such as manner and path within dynamic motion events.

At an early age, infants pay attention to the manner and path of a figure. For example, 5.5-month-olds aptly discriminated between real-life human actions such as brushing teeth and brushing hair even when the actions were performed with the same instrument (e.g., brushing hair and brushing teeth both with a toothbrush; Bahrick, Gogate, & Ruiz, 2002). Likewise, 6-month-olds distinguished a puppet jumping from a puppet falling (Sharon & Wynn, 1998; Wynn, 1996), suggesting that they attended to and discriminated components such as manner and path. Between 8 and 14 months, English-reared infants discriminated figures (e.g., a man vs. a woman) and grounds (e.g., a road vs. a field) in dynamic events (Göksun et al., 2011). Infants can also attend to manner and path simultaneously while viewing motion events. After being habituated to a simple animated motion event (e.g., a starfish doing jumping jacks while moving over a stationary ball), 7-month-olds dishabituated to motion events involving manner and/or path changes (e.g., manner change [the starfish engaging in "toe touching" while moving over the ball], path change [the starfish performing jumping jacks while moving under a stationary ball]; Pulverman, Song, Pruden, Golinkoff, & Hirsh-Pasek, 2013). This finding replicated the results found with English- and Spanish-learning 14- to 17-month-olds in an earlier study (Pulverman, Golinkoff, Hirsh-Pasek, & Buresh, 2008).

Although these studies demonstrated that infants possess the requisite skills to form categories of actions and events—namely, individuating and discriminating between different actions varying in manner or path—they did not look directly at infants' *categorization* of actions. These studies either familiarized or habituated infants to a single example of an action or event and suggested that they distinguished between two individual actions. These studies did not show, however, whether infants

abstracted a categorical representation from different instances of an action and used that representation to determine whether or not a new instance belonged to the same category.

The few studies that did examine infants' categorization of a figure's manner and path of motion were highly controlled, using animated, cartoon-like events. Building on Pulverman and colleagues' (2008, 2013) discrimination work, Pruden and colleagues (2012, 2013) assessed infants' categorization of invariant manners or paths in animated motion events. These studies used a preferential looking paradigm in which infants were shown multiple motion events that had an invariant manner (e.g., spinning) or path (e.g., over a ball) in familiarization. Then at test, infants were presented with two motion events not shown in familiarization, one of which contained the same invariant manner (or path) and the other of which did not. The rationale was that if infants had formed a category of events that had the same invariant manner (or path), infants would show a novelty preference for the test event that did not contain the invariant manner (or path). Pruden and colleagues (2012) found that 10-month-olds showed the ability to form a category of an invariant manner. A limitation of these studies was that the motion events consisted of a cartoon figure (i.e., a starfish) moving in an invariant manner (e.g., spinning in exactly the same manner and velocity across events) against a homogeneous black background. One could argue that the stimuli were far too simplistic to reflect what happens in the real world, particularly with respect to the figures and actions presented. This simplicity and the animated nature of the events leave open the question of when infants categorize more complex and realistic actions carried out by human agents against a natural backdrop—the type of actions and events infants see on a daily basis.

The current studies expand and improve on Pruden and colleagues' (2012) categorization work in three ways. First, rather than asking infants to simply abstract the manner performed by the same agent, we presented infants with five human actors performing the same manner of motion, marching, along five different paths. Thus, the stimuli instantiated the manner category with much greater variability than previous studies. Second, all of the actions took place in a natural setting—in front of a building—approximating actions that infants encounter in real life. Finally, the use of multiple actors enabled us to examine whether infants categorize abstractly across distinct actors.

To investigate prelinguistic infants' category formation, we used a preferential looking paradigm (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Golinkoff, Ma, Song, & Hirsh-Pasek, 2013; Hirsh-Pasek & Golinkoff, 1996). To evidence categorization, infants must first show that they can discriminate among the exemplars of the same category—the goal of Study 1. If discrimination between category exemplars is not shown, then categorization may only be an artifact of infants' inability to tell the difference between instances of the same action. Second, infants must show that they respond differently to within-category versus out-of-category exemplars (Cohen & Younger, 1983; Eimas & Quinn, 1994)—the goal of Study 2. Thus, in Study 1 we took on the first criterion and examined 10- to 12-month-olds' ability to discriminate among a diverse set of within-category exemplars of a human action, marching.

Study 1: Can 10- to 12-month-olds discriminate among different marching exemplars?

In addition to being a required condition for examining infants' categorization, a discrimination study of dynamic human actions is important in its own right. Pulverman and colleagues (2013) demonstrated that English-learning 7-month-olds detected manner and path changes in dynamic animated motion events. In Study 1, we asked whether infants before the end of the first year of life can discriminate changes in dynamic human actions in a complex natural setting. In the marching actions presented in the current study, two components, actor and path, were systematically varied at test to create two types of within-category variations: (a) a path variation (e.g., Mike marches across vs. Mike marches in a circle) and (b) an actor variation (e.g., Mike marches across vs. Kate marches across).

Method

Participants

A total of 27 10- to 12-month-old infants were included in the final sample ($M = 11.52$ months, $SD = 1.00$; 14 boys and 13 girls). All infants were from monolingual English-speaking households

and were full-term at birth. Infants were primarily from Caucasian middle-class families in two suburban communities in the northeastern United States. An additional 6 infants (18%) were tested but not included because of fussiness ($n = 2$), parental interference ($n = 1$; see "Procedure" section below for details), low attention ($n = 1$; watched for less than 50% of the time), experimenter error/coding issues ($n = 1$), and side bias ($n = 1$; attention to one side of the screen across the test trials was more than 75%) (see Golinkoff et al., 2013).

Apparatus

The visual stimuli were presented on a large, 44-inch television (TV) screen. When displayed full-screen, the image covered an area of 57.5 × 76 cm. Music was played through the built-in speakers of the TV during intertrial intervals; otherwise, all other trials during the study were nonlinguistic silent trials. A DVD player connected to the TV played the stimuli.

Stimuli

Dynamic events using human actors were created with no language accompanying these events. Five different human actors performed a marching action. Actors A and B were female, and actors C, D, and E were male. All wore different colors and types of clothes. Actor height appearing on the full screen ranged from 9 to 17.5 cm. Actors marched along five different paths relative to a set of steps in front of a campus building: across, forward/backward, in a circle, in a fixed position, and up–down the stairs. Table 1 describes these paths in full detail and further illustrates the differences among the actors' identities.

The exemplars not only differed in the path of the actor and the appearance of the actor but also differed in *how* each actor marched along each path; the way in which each actor performed the manner of marching varied. For example, the actors differed in how high they lifted their thighs and arms when marching. Furthermore, the same actors varied their marching depending on the path. Marching in a fixed position did not involve forward motion as marching across or forward and backward, whereas marching up and down stairs involved upward and downward motion. As a result, each actor needed to adjust his or her marching accordingly to be able to traverse the desired path. The key here is that infants were shown marching exemplars that contained a large amount of variability but that could all be considered exemplars of the manner of motion, marching.

Combining the various actors and paths yielded a total of 25 possible events that infants could potentially view (e.g., Actor A marching across, Actor A marching forward/backward, Actor E marching in a fixed position, Actor E marching up/down the stairs). From these 25 possible events, we randomly selected 19 events from which we formed 14 discrimination movies to be used in 14 between-participants conditions. Participants were randomly assigned to one of these 14 between-participants conditions.

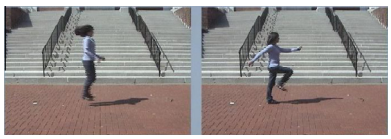
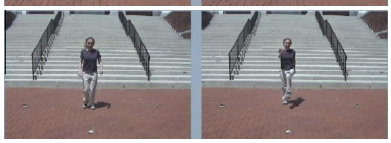
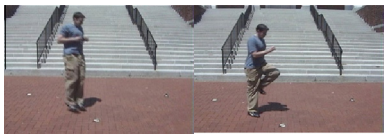
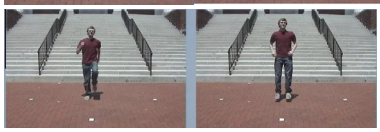
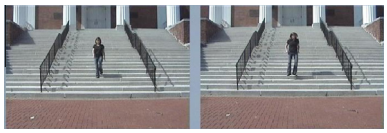
Procedure

Each infant sat on a parent's lap in front of a large TV screen and watched a short movie in a dimly lit room. The distance between infants' eyes and the screen was approximately 110 cm. The visual angle for the actors ranged from 5 to 9 degrees in full-screen displays. A hidden camera recorded infants' visual fixation on the TV screen for offline coding. Parents were instructed to keep their eyes shut during the movie, and all but one complied (that infant was excluded). The movie consisted of two phases: a familiarization phase and a test phase (see Table 2).

Familiarization phase. An actor performed a marching action across the same path (e.g., Actor A marches across) on the full TV screen. The event lasted for 6 s and was repeated for a total of 10 familiarization trials or 60 s of total familiarization time.

Intertrial stimulus. A 2-s video of a baby's smiling face accompanied by music was used in between familiarization and test trials to refresh infants' attention and to center their gaze before the next trial began.

Table 1
Descriptions of action stimuli presented in Studies 1 and 2.

Path	Examples of actions and actors	Description
"Across"		The actor starts from the left side of the scene, marching (or hopping with both legs) to the right side of the scene, turns around, and marches (or hops) back to the starting point
"Forward and backward"		The actor starts from the far end of the midline of the scene (at the foot of the stairs), marching (or hopping with both legs) forward toward the camera. As the actor reaches the marked end of the path, without any pause, he or she continues to march (or hop) backward back to the starting point
"In a circle"		The actor starts from the left side of the scene, marches (or hops with both legs) counterclockwise in a circle before returning to the starting point
"In a fixed position"		The actor stands in the middle of the red bricked area, marching (or hopping with both legs) in a fixed position continuously
"Up and down the stairs"		The actor starts from the sixth stair from the bottom, marches (or hops with both legs) down step by step until he or she reaches the bottom step. Then the actor turns around and marches (or hops) back up to the starting step

Test phase. Two 12-s test trials followed the familiarization phase, examining whether infants could discriminate between (a) marching actions across different *paths* (i.e., path discrimination trial) and (b) *actors* (i.e., actor discrimination trial). Test trials were also separated by the intertrial stimulus. During each test trial, infants were shown two events side by side for 12 s. One event was the very same event shown in the familiarization phase, whereas the other one was a novel event involving a change in either the path or the actor. The novel events always appeared on the opposite side of the screen across the two test trials. The order of the path and actor trials and the side on which the novel events appeared were counterbalanced across infants.

Coding and reliability. Trained research assistants, blind to the conditions of the participants and using the Supercoder program (Hollich, 2005), recorded the amount of time that (a) infants fixated on the screen during the familiarization trials and (b) infants fixated to the left and right of the screen during the test phase. Coding occurred frame by frame (a frame is 1/30 of a second). Videos of 29% of participants were recoded by a second coder. The mean intercoder reliability (Pearson's r) was .997.

Dependent variables and predictions

Familiarization phase. Infants' familiarization fixation (FF) was calculated for each trial by dividing the total looking times in the trial by the trial length (6 s). We predicted a significant decline of FF over the familiarization phase.

Test phase. A proportion of looking time to the novel event (PLN) was calculated for each child by dividing the looking time to the novel event at test by the total looking time to both the familiar and the novel events. This measure served as the dependent variable for the test trials. Proportions

Table 2
Study 1: Design of discrimination movies.

	Visual stimuli		Duration
Familiarization Trials 1 to 10	A marches across (full screen)		6 s per trial
Test 1 (path)	A marches *across* (left)	A marches *in a fixed position* (right)	12 s
Test 2 (actor)	*B* marches across (left)	*A* marches across (right)	12 s

Note. A and B refer to the two actors. Test order and target side were counterbalanced across infants.

above .50 meant that the infant looked at the novel event longer than at the familiar event, whereas proportions below .50 indicated that the familiar event was favored. Importantly, infants who discriminated between the two test events would show a significant preference for one event over the other during the test phase.

Results

Preliminary analyses found no significant main effects or interactions of child gender or condition when testing infants' FF or PLN (Fs < 2.60, ps > .35). Thus, data were collapsed across these variables in further analyses.

Familiarization phase

On average, infants fixated on the screen nearly the entire time during the first familiarization trial (M = .99, SD = .04). During the last familiarization trial, infants' attention decreased somewhat, but most infants still watched attentively (M = .88, SD = .20). Given that infants' FF was negatively skewed, a sign test was performed to assess whether the change in the distribution of infants' FF was significant. Indeed, on average infants' FF showed a significant decrease from the first familiarization trial to the last one (p < .001), suggesting that infants had been familiarized with the events.

Test phase

Path discrimination trial. Infants fixated on the novel event for an average of 6.28 s (SD = 2.66) versus an average of 4.09 s (SD = 2.40) on the familiar event; a paired-samples t-test using these raw looking time scores revealed a significant difference in looking to the novel event versus the familiar event, $t(26) = 2.50$, $p = .019$, $d = 0.86$. Furthermore, a test of the PLN indicated that infants looked at the novel event (M = .61, SD = .15) significantly longer than would be expected by chance, $t(24) = 3.58$, $p = .002$, $d = 0.73$; two infants did not attend to the screen during this trial and, thus, were not included (see Fig. 1). Of 25 infants, 18 (72%) showed a preference for the novel event, which was significantly higher than would be observed by chance ($\chi^2 = 4.84$, $p = .028$). Taken together, these results show that infants looked significantly longer at the novel event than at the familiar event in the path discrimination trial.

Actor discrimination trial. Infants' looking times for the novel and familiar events during the actor discrimination trial were 5.79 s (SD = 2.84) and 4.39 s (SD = 2.73), respectively; a paired-samples t-test showed that infants did not look significantly more at one event than at the other, $t(26) = 1.40$, $p = .17$, $d = 0.50$. A test of the PLN indicated that infants did not look at the novel event (M = .56, SD = .23) significantly longer than would be expected by chance, $t(25) = 1.39$, $p = .18$, $d = 0.26$; one infant did not attend to the screen in this trial and was not included (see Fig. 1). Of 26 infants, 16 (62%) showed a novelty preference, which was not significantly different from what would be expected by chance ($\chi^2 = 1.39$, $p = .239$).

Post hoc analysis of actor discrimination trial. Although no significant looking preference was seen for the actor discrimination across the full 12-s trial, it was possible that the looking preference did emerge but did not last for the entirety of the trial. As Quinn and Intraub (2007) argued, in a long enough test trial, infants' novelty preference will eventually subside because the novel stimulus

becomes increasingly familiar as the test trial continues. To capture a possible initial burst of novelty preference, we examined the PLN during the first and second halves of the actor discrimination trial (i.e., first 6 s vs. last 6 s). Although a test of the looking times for the first half of the trial indicated that infants did not look longer at the novel event (M = 2.91, SD = 1.29) than at the familiar event (M = 2.16, SD = 1.29), $t(26) = 1.68$, $p = .104$, $d = 0.32$, the PLN was significantly higher than would be expected by chance (M = .59, SD = .21), $t(24) = 2.12$, $p = .044$, $d = 0.43$ (see Fig. 2). However, neither the comparison of looking times to the novel event (M = 2.88, SD = 1.92) and familiar event (M = 2.23, SD = 1.76), $t(26) = 0.99$, $p = .333$, $d = 0.19$, nor the comparison of PLN (M = .55, SD = .33) with chance level, $t(24) = 0.82$, $p = .421$, $d = 0.15$, showed significant difference during the second half of the trial.

Discussion

The results of Study 1 show that 10- to 12-month-olds are capable of discriminating between dynamic intransitive events. Specifically, they can distinguish between events of a human actor marching along different paths (and possibly between events of different actors marching along the same paths).

Previous research showed that 7- to 9-month-olds noticed differences in paths in dynamic events when an animated figure performed the paths in an invariant manner (Pulverman et al., 2013). The current results extend these previous findings by demonstrating that infants can reliably discriminate among changes in the figure's path even when the figure is a complex human actor and when the action takes place in a more naturalistic setting. Infants' discrimination of these events is a critical prerequisite to forming categories that consist of these events.

Infants also displayed an ability to discriminate between two events that differed in the actor. Although discrimination of the actor changes were weaker than those found for the path changes, infants had a significant preference for the novel actor during the first half of the test trial, suggesting that they did indeed discriminate among the actors. Although these results are post hoc in nature, the lack of significant preference during the second half of the test trial suggests that differences among actors might not be salient enough to preverbal infants to hold their attention for the full 12-s test trial. Why might this be the case? Research suggests that actions (and changes in actions) may simply be more salient than faces and/or agent changes (Bahrick & Newell, 2008; Bahrick et al., 2002). Alternatively, a quickly subsiding novelty response, such as the one seen in our actor discrimination trial, may actually be an indicator of *increased* sensitivity to actor identity as opposed to decreased sensitivity (Quinn & Intraub, 2007). Regardless of the explanation for subsiding novelty preference during

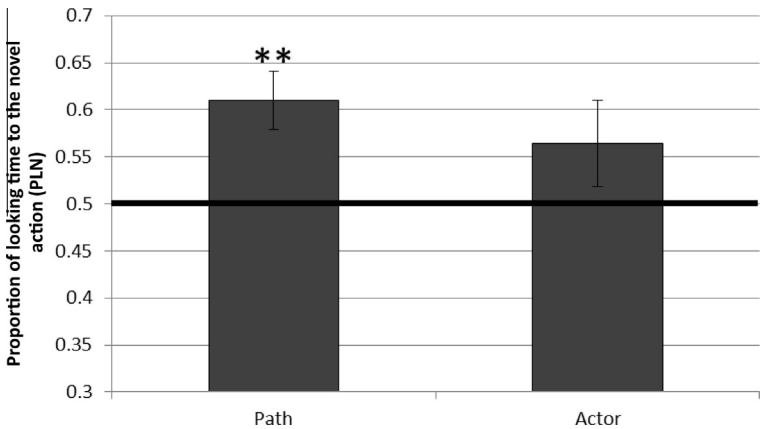


Fig. 1. Study 1: Infants' proportion of looking time to the novel action (PLN) during the path and actor discrimination trials at test. Error bars represent standard errors. $^{**}p < .005$.

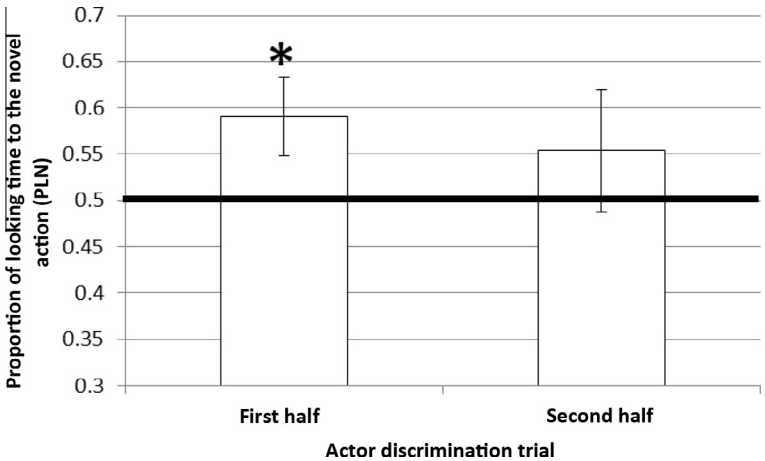


Fig. 2. Study 1: Infants' proportion of looking time to the novel action (PLN) during first and second halves of the actor discrimination trial at test. Error bars represent standard errors. $^{*}p < .05$.

the actor discrimination trial, we see evidence that 10- to 12-month-olds recognize that something has changed during the actor discrimination trial.

Study 2: Can 10- to 12-month-olds form categories of dynamic human actions?

Study 1 showed that 10- to 12-month-olds can discriminate between exemplars of an intransitive human action (i.e., marching) across various paths. Evidence of such discrimination is an important prerequisite for the claim that infants categorize actions across different paths. In Study 2, we examined whether 10- to 12-month-olds show evidence of categorization of marching based on those diverse exemplars from Study 1. To make the argument for categorization, the design must meet two criteria, namely that (a) a variety of different stimuli from a single action category must be presented during the familiarization phase and (b) during the test phase infants must be presented with two novel stimuli: a within-category novel stimulus and an out-of-category novel stimulus (Quinn, 2002; see also Pruden et al., 2012, 2013). Study 2, like Study 1, used the nonlinguistic preferential looking paradigm (Golinkoff et al., 1987, 2013; Hirsh-Pasek & Golinkoff, 1996) with two major differences from Study 1.

First, instead of seeing the same event repeatedly, infants were familiarized with videos of different examples of marching (e.g., Mike marches across, Kate marches in a circle, Joe marches forward and backward). Second, at test infants were shown two new actions side by side, one of which was a new example of the familiar action (e.g., Laura marches up and down the stairs; in-category event) and the other of which was a novel action performed by the same actor along the same path (e.g., Laura hops up and down the stairs; out-of-category event). Because the two test events occurred on the same path and involved the same actor, the only basis for infants to show a preference for one video over the other was the manner of the action.

Furthermore, the two test videos were also shown before the familiarization phase to determine whether infants had any a priori salience preference for either test event. If no a priori preference for either test event emerges, preference for one action over the other during the test phase can only be taken as evidence of categorization. If infants extract the commonalities between the variable actions shown in familiarization and evidence categorization of the action, they should display a significant preference for one of the events at test. If infants fail to categorize, both actions during the test phase should look novel and not elicit any differential looking patterns. This exact design and setup was successfully used in published studies by Pruden and colleagues (2012, 2013). The intention of the design was to reveal the effect of the familiarization phase on infants' looking preference across

two actions that were shown both before and after the familiarization phase. Because the test event pairs were identical to the salience event pairs, a significant novelty preference during the test phase, in contrast to a lack of a significant preference during the salience phase, would suggest an impact of the familiarization phase and evidence of successful categorization (see Golinkoff et al., 2013, for more information about the reliability and validity of the design).

Method

Participants

A total of 28 10- to 12-month-old infants (M = 11.29 months, SD = 0.99; 13 boys and 15 girls) formed the final sample in Study 2. As in Study 1, all infants were from monolingual English-speaking households, were full-term at birth, and were recruited primarily from Caucasian middle-class families. An additional 13 infants (31%) were tested but not included in the final sample because they looked only at one side of the screen during salience (n = 3) or test (n = 1), were too fussy (n = 3), had "low attention" (n = 2), or experienced experimental error (n = 3) or because of parental interference (n = 1).

Stimuli

To assess whether infants had indeed formed a category of *marching,* we included examples of another category, *hopping* (see Table 1). These hopping actions were performed by the same actors and filmed in the same setting. The paths traversed by the actors in the hopping exemplars were the same as those in the marching exemplars.

Procedure

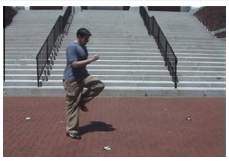
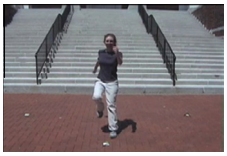
Infants participated in three phases of the experiment: salience, familiarization, and test (see Table 3).

Salience phase. A single 12-s trial presented two 6-s action clips side by side twice (the videos were looped once). The two action clips were a hopping action (i.e., out-of-category event) and a marching action (i.e., in-category event) performed by the same actor (e.g., Actor A). The two videos were separated by a 2-cm gap against a light gray background on the TV screen. This trial was subsequently presented again during the test phase. The purpose of the salience phase was to assess infants' a priori preference for these test events. The sides of the actions in the salience phase (as at test) were counterbalanced across infants.

Familiarization phase. Infants viewed eight 6-s familiarization events/trials for a total of 48 s of familiarization exposure. Familiarization trials were presented sequentially on the full TV screen, with trials separated by the same intertrial stimulus used in Study 1. In the first four familiarization trials, Actors B, C, D, and E performed the same manner of motion, marching, each across a different path (i.e., Actor B marching forward and backward, Actor C marching in a circle, Actor D marching in a fixed position, and Actor E marching up and down the stairs). In the remaining four familiarization trials, Actors B, C, D, and E continued to perform the same manner of motion, marching, but now along a new path each actor had not previously traversed during the first four trials (i.e., Actor B marching in a circle, Actor C marching in a fixed position, Actor D marching up and down the stairs, and Actor E marching forward and backward). Thus, infants saw each actor perform the marching action along two different paths in a total of eight familiarization trials. The order of the actors and the paths during the first and second halves of the familiarization phase were randomly determined for each of the four between-participants conditions. For example, infants randomly assigned to Condition 4 viewed Actor B marching in a circle, Actor C marching up and down the stairs, Actor D marching in a fixed position, Actor E marching forward and backward, Actor B marching up and down the stairs, Actor C marching in a fixed position, Actor E marching in a circle, and finally Actor D marching forward and backward during the familiarization phase.

Test phase. The test phase was identical to the salience phase.

Table 3
Study 2: Design of categorization movies and action exemplars.

		Visual stimuli		Examples	Duration
Salience		A hops across	A marches across		12 s
Familiarization	Trials 1 to 4	B, C, D, and E march along four different paths (in a circle, in a fixed position, forward and backward, and up and down the stairs)			6 s per trial
	Trials 5 to 8	B, C, D, and E each march along another path of the four paths			
Test		A hops across	A marches across		12 s

Note. A, B, C, D, and E refer to the five actors.

Coding and reliability. The coding and reliability checking procedures were identical to those of Study 1. The intercoder reliability (Pearson's *r*) was .998.

Dependent variables and predictions

Familiarization phase. Infants' familiarization fixation was calculated in the same way as in Study 1. Because all of the familiarization exemplars were different from one another, a systematic decrease of FF would suggest that infants perceived the commonality (the same manner, marching) across these exemplars, thereby providing indirect evidence for infants' categorization of these action exemplars.

Test phase. A proportion of looking time to the out-of-category event (PLO) was calculated for each child by dividing the looking time to the out-of-category event at test by the total looking time to both the in-category and out-of-category events. This measure served as the dependent variable for the salience and test trials. Proportions above (or below) .50 in the salience trial meant that infants had an a priori preference for the out-of-category or in-category event. Proportions above .50 during test meant that infants looked at the out-of-category event longer than at the in-category event, whereas proportions below .50 indicated that the in-category event was preferred over the out-of-category event. Critically, those infants who evidenced successful categorization of the marching action would show a significant preference for one action over the other at test.

Results

Preliminary analyses found no significant main effects or interactions of child gender and condition when testing infants' FF or their PLO during salience and test ($Fs < 3.07$, $ps > .05$). Thus, we collapsed the data across these variables in further analyses.

Salience phase

On average, infants looked at the screen (either side) 84% of the time across the 12-s trial. They looked at the marching action (in-category event) for 5.22 s (SD = 2.67) and looked at the hopping action (out-of-category event) for 4.81 s (SD = 2.45); a paired-samples t-test showed that infants did not look significantly more at one event than at the other, $t(27) = 0.441$, $p = .66$, $d = 0.16$. Infants' PLO during the salience phase ($M = .48$, $SD = .24$) was not different from chance looking, $t(27) = -0.37$, $p = .713$, $d = 0.08$. Thus, infants did not show an a priori preference for either test event during the salience phase; that is, prior to the familiarization phase, infants found both potential test events to be equally interesting.

Familiarization phase

We conducted a repeated-measures analysis of variance (ANOVA) with infants' FF in each familiarization trial as the within-participants dependent variable. A significant main effect of FF emerged, suggesting significant differences among the FFs across familiarization trials, $F(7, 189) = 5.54$, $p < .001$, $\eta_p^2 = .17$. Notably, there was a significant linear trend, $F(1, 27) = 8.07$, $p = .008$, $\eta_p^2 = .23$, as well as a significant cubic trend of infants' FF, $F(1, 27) = 7.79$, $p = .01$, $\eta_p^2 = .22$. This significant cubic trend was explained by infants' initial decrease in FF during the first four trials, a slight increase in their attention during the next three trials, and a final decrease during the last trial (see Fig. 3). Recall that after the first four familiarization trials, the manner of motion, *marching,* was performed again by the same actors but now in novel combinations of previously presented paths. Infants' renewed interest during the second half of the familiarization phase seems to suggest that they noticed the change in the combinations. These patterns indicated that infants processed the diverse exemplars of marching and noticed both the differences (as suggested by the renewed attention) and the commonalities (as suggested by the overall decreased FF) among the various examples.

Test phase

On average, infants looked at the screen (either side) 76% of the time across the 12-s trial. They looked at the marching actions (in-category event) for 3.59 s (SD = 1.98) and looked at the hopping actions (out-of-category event) for 5.50 s (SD = 2.63); a paired-samples t-test showed that infants looked significantly more at one event than at the other, $t(27) = 2.62$, $p = .014$, $d = 0.82$. Infants' PLO ($M = .60$, $SD = .19$) was significantly different from that expected by chance, with infants showing a significant preference for the out-of-category event (i.e., hopping), $t(27) = 2.75$, $p = .01$, $d = 0.53$. Infants' PLO during the salience and test phases are plotted in Fig. 4. Furthermore, of the 28 infants tested, 21 (75%) showed a preference for the out-of-category event during the test phase ($\chi^2 = 7.00$, $p = .008$). Thus, infants had indeed showed evidence of categorization of marching, which excluded hopping, but included the novel marching event at test.

Discussion

Study 2 found that 10- to 12-month-olds evidenced categorization of dynamic human action (i.e., marching) performed by different actors and across different paths. This finding was supported by three results. First, infants showed no a priori preference for either a marching or hopping action during the salience phase. Yet, after familiarization to other exemplars of marching, infants significantly preferred to look at the out-of-category action, hopping. This preference suggests that infants showed categorization of marching that did not include hopping events. Second, significantly more infants than would be expected by chance showed a preference for the out-of-category action, hopping, at test. Finally, the pattern of infants' attention during the familiarization phase also suggested that infants noticed the common manner across the different marching exemplars and grouped them together. Together, these results indicate that infants categorize at least some intransitive human actions between 10 and 12 months of age.

The current experimental design allowed us to use the test actions as their own salience preference controls. The novelty preference at test—but not at salience—was good evidence for the direct impact of the familiarization phase. Thus, repeated exposure to examples of one category made the out-of-category action appear to be "novel" to infants afterward despite the appearance of the action once in the salience trial.

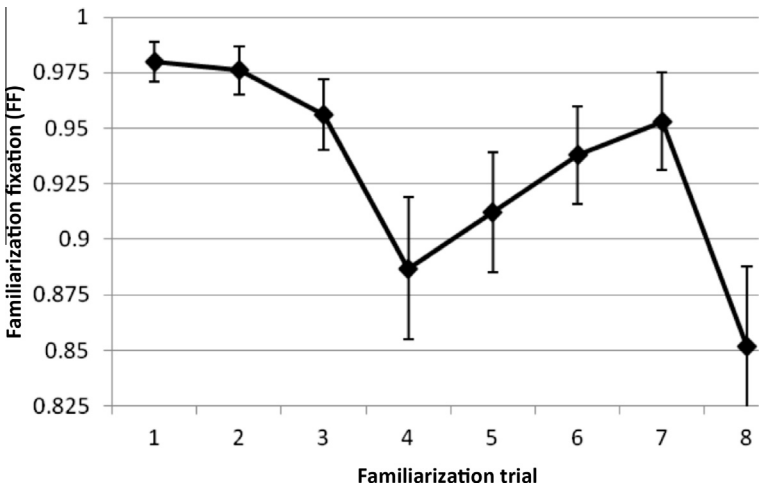


Fig. 3. Study 2: Infants' attention (FF) during the familiarization phase. Error bars represent standard errors.

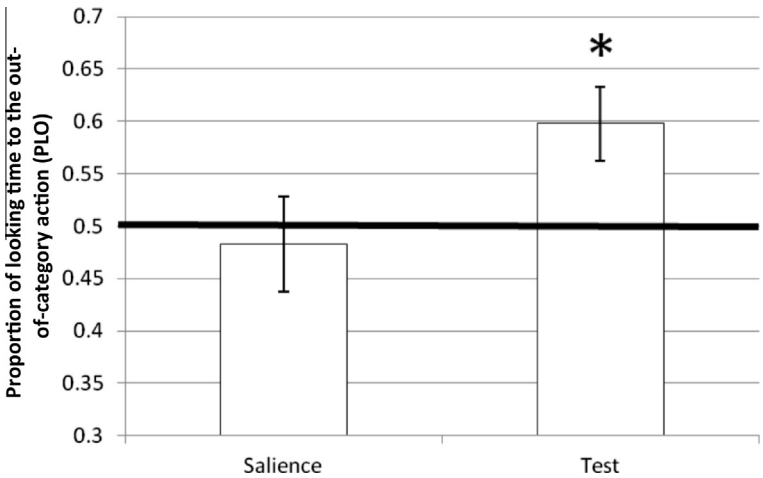


Fig. 4. Study 2: Infants' proportion of looking time to the out-of-category action (PLO) during the salience and test phases. Error bars represent standard errors. $^{*}p < .05$.

Presenting the identical events at both salience and test may have caused some potential interference. It is possible that prior exposure to the out-of-category test action (hopping) desensitizes infants and dampens their novelty preference toward hopping at test. It is also possible that prior exposure to the within-category test action (marching) made infants more familiar with the marching action and increased the "novelty" of hopping at test. However, when looking at aggregated results, the effects of these two possibilities should cancel out and the remaining novelty effect should be taken as categorization evidence above and beyond potential interference inherent to the design.

General discussion

In two studies using a nonlinguistic preferential looking paradigm, we examined 10- to 12-month-olds' discrimination and categorization of naturalistic, complex, and highly diverse dynamic marching actions. Study 1 showed that infants discriminated among marching actions across different paths and

actors. Study 2 showed that infants categorized the marching actions, showing a novelty preference to a hopping action over a marching action after seeing a set of highly diverse marching events.

The discrimination test in Study 1 addresses an important question about infants' event processing: Can infants discriminate between human actions involving different paths and actors? This ability is crucial for human cognition because the identity of a human actor and the path the actor traverses may bear important information on the goal of the actor as well as the consequence of the action. Moreover, this ability is prerequisite to learning language, especially verbs and prepositions, which often encode the path of an action. Our results revealed that infants showed discrimination between marching actions with different paths and actors. The finding of infants' discrimination of paths in naturalistic complex events extends previous research (Pulverman et al., 2008, 2013) involving stripped down animations, demonstrating infants' important event processing skills foundational for categorization of events. With respect to actor discrimination, a post hoc analysis revealed that infants displayed an ability to recognize that something regarding the actor identity had changed. Together, these discrimination results indicate that the marching actions to be used in the categorization study were perceived by the infants as highly different from each other, satisfying a prerequisite condition for evidencing categorization.

In light of infants' successful categorization of the marching actions in Study 2, several questions arise. First, was infants' performance a result of categorical responses or merely a reaction to perceptual similarities and differences that were not category-based? This question has always been a point of argument in the categorization literature, but a few lines of investigations support the former view rather than the latter one. For example, in a set of studies investigating infants' processing of the ground in action scenes, Göksun and colleagues (2011) found that 14-month-old English-learning infants showed categorical distinctions for two types of grounds that are lexicalized by two different ground–path verbs in Japanese: *wataru* (go across a flat barrier dividing two points, e.g., a road or a bridge) and *tooru* (go across a continuous plane, e.g., a tennis court or a field). That is, in a discrimination procedure similar to the one in the current research, infants showed a novelty preference only when the two grounds shown in the events each came from one of the two categories, but not when both grounds were from the same category. This finding argues against the notion that infants simply reacted to the perceptual similarity or difference among the stimuli. Furthermore, when the grounds were presented in static scenes, infants differentiated grounds both within and across categories, a behavior indicative of detection of perceptual differences rather than a categorical response. The hypothesis was that the static scenes lost the foundation to be categorized as grounds because no movement indicated the starting and ending points of the grounds and, therefore, it was not clear whether the ground extended in a line or in a plane.

Another example of how these kinds of events may be viewed categorically and not just from the vantage point of perceptual similarity comes from the work of Pruden and colleagues (2013). In that study, infants failed to form a category of path with animated stimuli when the ground object (i.e., the ball) was removed. If infants categorized the path simply based on perceptual similarity, the absence of the ground object should not have affected their performance. However, the fact that their categorization of path was contingent on the presence of the ground object suggests that infants relied on the *relation* between the figure's movement and the ground object to categorize path information. Finally, another study explicitly pitted a change in relations against a change in perceptual features (Roseberry, Göksun, Hirsh-Pasek, & Golinkoff, 2012). That study suggests that infants prefer to encode relations rather than metric changes that are simply perceptual. Roseberry and colleagues (2012) changed either the relationship between the figure and the ground (i.e., over vs. under) or the distance between them of the same absolute magnitude. Yet only when the figure moved from over to under the ball did 10-month-olds renew their looking. They did not respond when the figure moved the same amount but did not change its relationship to the ball. These studies corroborate and extend previous research investigating younger infants' categorization of spatial relations of *above* and *below* in *static* displays (Quinn, 1994; Quinn, Cummins, Kase, Martin, & Weissman, 1996; Quinn, Polly, Furer, Dobson, & Narter, 2002). Thus, although similarity in motion rather than categorical representation may also explain infants' behavior in the current study, it is not likely based on evidence from earlier studies.

Second, did infants form the category during the course of the experiment or did they enter the experiment in possession of a category of marching? From a perceptual and motor standpoint, infants probably have not seen many marching instances during their short lives, although it is possible that some infants have had prior exposure (e.g., watching parade on the street or in the media); neither can they carry out a marching action. From a linguistic standpoint, there is little reason to believe that these infants understood the word *march*, and at this age they do not have many other action words in their small receptive vocabularies. On average, infants understood and/or said 11 action words and prepositions according to parents, and none reported that *march* was one of them. Therefore, we think it is unlikely that infants entered the experiment with a category of marching in place. However, it can be argued that a marching action is an exaggerated walking action and that 10- to 12-month-olds may already possess a category of "walking" because 10- to 12-month-olds have seen many walking examples and some have begun to walk themselves. Furthermore, normed data of infants and toddlers learning American English suggest that 50% of infants comprehend *walk* at 13 months of age (Fenson et al., 1994).

Did infants form a category of marching during the course of the experiment, or did they perform the task by extending an existing category of walking to include the marching instances but exclude the hopping instances? Both scenarios are plausible; our findings cannot directly answer this question. Past research has examined whether infants' prior exposure (if any) to the tested category is related to categorization performance (Quinn, 2006). However, even when such results are obtained in experiments that are designed to study category formation, it is difficult to completely rule out the possibility that infants may recruit from a preexisting knowledge base (Quinn, 2006).

Whether infants formed a category of marching after being familiarized with the marching exemplars during the experiment or aligned the marching exemplars with a preexisting marching or walking category, the current results suggest that infants appeared to have a categorical understanding of marching (or walking) such that a highly diverse set of marching exemplars fell into this category, whereas hopping instances were excluded. Crucially, the experiment demonstrated that infants possessed the cognitive abilities required for forming categories of actions, thereby leading to the third question: How did infants achieve categorization of the marching actions?

Compared with prior action categorization research (e.g., Pruden et al., 2012), our stimuli were more realistic, using human actors rather than animated events, and were more complex, requiring that infants abstract across multiple paths and multiple actors. To categorize these complex realistic marching actions, infants must distinguish the moving figures from the background. Next, infants must attend to the actions and extract a common movement pattern (i.e., marching) across the familiarization exemplars, in which the actors marched along a number of different paths in their idiosyncratic ways, and must mine the perceptual information such as the movements of the arms, legs, and the whole body so as to form abstract representations of these actions. Importantly, the use of different paths also meant that different parts of the actors' bodies were visible at different times during the action and on different parts of the screen. For example, actors' bodies were seen frontally (going down the stairs), from a posterior view (going up the stairs), or laterally (marching moving along the width of the screen). The different paths also required the actors to adjust their gait accordingly to traverse the desired paths (e.g., ascending the stairs, marching along a circle). Therefore, categorizing marching across these different paths was a challenging task. On the other hand, the magnitude of variability among the current action exemplars approximates what infants are likely to observe in vivo.

Furthermore, infants must compare the two test actions, both of which differed from the previous actions, to recognize that one of them contained the common movement pattern, whereas the other one did not. Because the two test actions were carried out by the same actor along the same path, infants based their preference solely on the manner of the action. Thus, the results suggest that infants showed an abstract categorical representation of marching independent of the path and actor. This categorical representation enabled infants to identify another in-category exemplar and exclude out-of-category actions from this category. Despite these positive findings, more work needs to be conducted to ensure that infants can apply this categorization ability to other novel dynamic human actions, including the action of hopping, among other types of actions. Our current work addresses

these challenges by including additional actions as well as by testing the effects of language on category formation.

Fourth, how is infants' nonlinguistic categorization of actions related to verb learning? A number of studies suggest that infants categorically represent dynamic events prior to acquiring the language that encodes those events. For example, unlike adult English speakers, 5-month-old English-reared infants showed sensitivity to the distinction between "tight" and "loose" fit of one object to another, a conceptual distinction marked in Korean but not in English, suggesting that infants possess "universal, pre-existing representations of ... meaning" (Hespos & Spelke, 2004, p. 453). Similarly, McDonough, Choi, and Mandler (2003) demonstrated that 9- to 14-month-old English-reared infants showed categorization of the tight- and loose-containment relations in dynamic events, whereas adult English speakers did not show such categorization, confirming the notion that infants have preverbal concepts (Mandler, 1996). Furthermore, Göksun and colleagues (2011) found that although both English-learning and Japanese-learning infants showed a categorical discrimination of grounds at 14 months of age, only Japanese-learning infants continued to do so at 19 months. Göksun, Hirsh-Pasek, and Golinkoff (2010) presented the thesis that infants start with language-general nonlinguistic constructs that are gradually refined and tuned to the requirements of their native language.

This process of refining and tuning may explain why although the foundation for verb learning seems to be in place between 10 and 12 months of age, toddlers and even preschoolers have difficulty in learning and extending verbs, especially compared with the rapidity with which they learn and extend nouns (e.g., Childers & Tomasello, 2006; Gentner, 1982; Golinkoff, Hirsh-Pasek, Bailey, & Wenger, 1992; Golinkoff, Jacquet, Hirsh-Pasek, & Nandakumar, 1996; Hollich, Hirsh-Pasek, & Golinkoff, 2000; Imai et al., 2008). Forming a nonlinguistic action category such as marching does not imply that infants will readily learn this category's name. In fact, finding the component of the action that a verb category names may be where the biggest challenge lies (Maguire, Hirsh-Pasek, & Golinkoff, 2006). Dynamic human actions can contain a number of components that can be labeled such as figure, ground, path, manner, source, goal, instrument, outcome, and cause (e.g., Talmy, 1985). Languages exhibit tremendous flexibility and complexity in how they package these components in relational terms such as verbs and prepositions (e.g., Gentner, 1982; Gentner & Boroditsky, 2001; Gentner & Bowerman, 2009; Golinkoff & Hirsh-Pasek, 2008; Golinkoff et al., 2002; Göksun et al., 2010; Snedeker & Gleitman, 2004; Tomasello, 1995). This flexibility and complexity exists both within a language and across languages. For example, in English a person can be running, hurrying, exiting, and escaping—all at the same time. Cross-linguistically, the same action can be called *marching* in English but *walking in a particular way* in Chinese. Thus, children must not only find commonalities in dynamic actions and relations without language—the topic of this investigation—but also discern *which* component of an action is mapped onto a relational category in a particular language. Therefore, children's initial nonlinguistic categories may interact with and become shaped by the ambient language (Bowerman & Choi, 2003; Gentner & Bowerman, 2009; Göksun et al., 2010; Hespos & Spelke, 2004; Maguire et al., 2010; McDonough et al., 2003). We are currently investigating this hypothesis with older infants.

There is also a need to see whether children who are more successful in forming action categories between 10 and 12 months of age will continue to be better verb learners as their vocabularies expand. In fact, research from our labs using a different set of realistic stimuli suggests that there is a positive relationship between infants' ability to form nonlinguistic categories of event components at 13 to 15 months of age and their subsequent verb learning during the third year of life (Konishi, Stahl, Golinkoff, & Hirsh-Pasek, 2016). Furthermore, that relationship appears to be independent of the number of nouns children have at that later time. Given the relative difficulty that children with specific language impairment and autism have with verb learning (Parish, Hennon, Hirsh-Pasek, Golinkoff, & Tager-Flusberg, 2007), finding these relationships in typical children is tantalizing and may offer one potential candidate for early intervention. Clearly, numerous research questions remain. Further longitudinal research holds great potential for understanding the link between infants' early perception and categorization of dynamic events and their later language learning.

Across two studies, we demonstrated that by the end of the first year of life, infants evidence the ability to abstract perceptual commonalities from nonlinguistic dynamic human actions—actions that may be potential referents for English motion verbs. A handful of studies have examined infants' abil-

ity to discriminate among and categorize across *dynamic actions*. Thus, the research presented in the current article represents a unique contribution to the literature on infants' categorization and on the precursors to learning names for actions.

Acknowledgments

This research was funded by grants to the third and fourth authors from the National Science Foundation (NSF, SBR9615391), the National Institutes of Health (NIH, RO1HD050199), and the Institute of Education Sciences (IES, R305A100215). The studies reported here were part of the first author's dissertation submitted to the University of Delaware. Special thanks go to Paul Quinn for advice and mentorship in these studies and three anonymous reviewers for providing comments on earlier drafts of this manuscript. The authors acknowledge the invaluable assistance of former laboratory coordinators Amanda Brandone, Rebecca Seston, Wendy Shallcross, and Aimee Stahl; former graduate student Weiyi Ma; all other members of the Child's Play, Learning, and Development Lab at the University of Delaware (formerly the Infant Language Project); and the Temple University Infant and Child Laboratory, as well as Bianca Graves and other staff members and teachers at the Early Learning Center at the University of Delaware, in recruiting participants, conducting the experiments, and providing comments and suggestions. Finally, we express our deepest gratitude to all of the families who participated in this research.

References

Bahrick, L. E., Gogate, L. J., & Ruiz, I. (2002). Attention and memory for faces and actions in infancy: The salience of actions over faces in dynamic events. *Child Development, 73*, 1629–1643.

Bahrick, L. E., & Newell, L. C. (2008). Infant discrimination of faces in naturalistic events: Actions are more salient than faces. *Developmental Psychology, 44*, 983–996.

Baillargeon, R. (2004). Infants' physical world. *Current Directions in Psychological Science, 13*, 89–94.

Baldwin, D. A., Andersson, A., Saffran, J., & Meyer, M. (2008). Segmenting dynamic human action via statistical structure. *Cognition, 106*, 1382–1407.

Baldwin, D. A., Baird, J. A., Saylor, M. M., & Clark, A. M. (2001). Infants parse dynamic actions. *Child Development, 72*, 708–717.

Bowerman, M., & Choi, S. (2003). Space under construction: Language-specific spatial categorization in first language acquisition. In D. Gentner & S. Goldin-Meadow (Eds.), *Language in mind: Advances in the study of language and thought* (pp. 387–427). Cambridge, MA: MIT Press.

Bruner, J. S., Goodnow, J. J., & Austin, G. A. (1956). *A study of thinking*.Oxford, UK: Wiley.

Childers, J. B., & Tomasello, M. (2006). Are nouns easier to learn than verbs? Three experimental studies. In K. Hirsh-Pasek & R. M. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 311–335). New York: Oxford University Press.

Cohen, L. B., & Younger, B. A. (1983). Perceptual categorization in the infant. In E. Scholnick (Ed.), *New trends in conceptual representation* (pp. 197–220). Hillsdale, NJ: Lawrence Erlbaum.

Eimas, P. D., & Quinn, P. C. (1994). Studies on the formation of perceptually based basic-level categories in young infants. *Child Development, 65*, 903–917.

Elsner, B., Hauf, P., & Aschersleben, G. (2007). Imitating step by step: A detailed analysis of 9- to 15-month-olds' reproduction of a 3-step action sequence. *Infant Behavior & Development, 30*, 325–335.

Fenson, L., Dale, P. S., Reznick, J. S., Bates, E., Thal, D. J., & Pethick, S. J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development, 59*(5) [Serial No. 242].

Gentner, D. (1982). Why nouns are learned before verbs: Linguistic relativity versus natural partitioning. In S. A. Kuczaj, II (Ed.), *Language development. Language, thought, and culture* (Vol. 2, pp. 301–334). Hillsdale, NJ: Lawrence Erlbaum.

Gentner, D., & Boroditsky, L. (2001). Individuation, relativity, and early word learning. In M. Bowerman & S. Levinson (Eds.), *Language acquisition and conceptual development* (pp. 215–256). Cambridge, UK: Cambridge University Press.

Gentner, D., & Bowerman, M. (2009). Why some spatial semantic categories are harder to learn than others: The typological prevalence hypothesis. In J. Guo, E. Lieven, S. Ervin-Tripp, N. Budwig, S. Özçaliskan, & K. Nakamura (Eds.), *Crosslinguistic approaches to the psychology of language: Research in the tradition of Dan Isaac Slobin* (pp. 465–480). Mahwah, NJ: Lawrence Erlbaum.

Göksun, T., Hirsh-Pasek, K., & Golinkoff, R. M. (2010). Trading spaces: Carving up events for learning language. *Perspectives on Psychological Science, 5*, 33–42.

Göksun, T., Hirsh-Pasek, K., Golinkoff, R. M., Imai, M., Konishi, H., & Okada, H. (2011). Who is crossing where? Infants' discrimination of figures and grounds in events. *Cognition, 121*, 176–195.

Goldin-Meadow, S., & Zheng, M. (1998). Thought before language: The expression of motion events prior to the impact of a conventional language model. In P. Carruthers & J. Boucher (Eds.), *Language and thought: Interdisciplinary themes* (pp. 26–54). New York: Cambridge University Press.

Golinkoff, R. M., Chung, H. L., Hirsh-Pasek, K., Liu, J., Bertenthal, B. I., Brand, R., ... Hennon, E. (2002). Young children can extend motion verbs to point-light displays. *Development Psychology, 38*, 604–614.

Golinkoff, R. M., & Hirsh-Pasek, K. (2006). Introduction: Progress on the verb learning front. In K. Hirsh-Pasek & R. M. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 3–28). New York: Oxford University Press.

Golinkoff, R. M., & Hirsh-Pasek, K. (2008). How toddlers begin to learn verbs. *Trends in Cognitive Sciences, 12*, 397–403.

Golinkoff, R. M., Hirsh-Pasek, K., Bailey, L., & Wenger, N. (1992). Young children and adults use lexical principles to learn new nouns. *Developmental Psychology, 28*, 99–108.
Golinkoff, R. M., Hirsh-Pasek, K., Cauley, K. M., & Gordon, L. (1987). The eyes have it: Lexical and syntactic comprehension in a new paradigm. *Journal of Child Language, 14*, 23–45.
Golinkoff, R. M., Jacquet, R. C., Hirsh-Pasek, K., & Nandakumar, R. (1996). Lexical principles may underlie the learning of verbs. *Child Development, 67*, 3101–3119.
Golinkoff, R. M., Ma, W., Song, L., & Hirsh-Pasek, K. (2013). Twenty-five years using the intermodal preferential looking paradigm to study language acquisition: What have we learned? *Perspectives on Psychological Science, 8*, 316–339.
Hespos, S. J., Saylor, M. M., & Grossman, S. (2009). Infants' ability to parse continuous actions series. *Developmental Psychology, 45*, 575–585.
Hespos, S. J., & Spelke, E. S. (2004). Conceptual precursors to language. *Nature, 430*, 453–456.
Hirsh-Pasek, K., & Golinkoff, R. M. (1996). *The origins of grammar: Evidence from early language comprehension*.Cambridge, MA: MIT Press.
Hirsh-Pasek, K., & Golinkoff, R. M. (Eds.). (2006). *Action meets word: How children learn verbs*. New York: Oxford University Press.
Hollich, G. (2005). *Supercoder: A program for coding preferential looking* (Version 1.5) [computer software].West Lafayette, IN: Purdue University. Available at: <http://www1.psych.purdue.edu/~ghollich/Splitscreen/index.html>.
Hollich, G. J., Hirsh-Pasek, K., & Golinkoff, R. M. (2000). Breaking the language barrier: An emergentist coalition model for the origins of word learning. *Monographs of the Society for Research in Child Development, 65*(3) (with Hennon, E., Chung, H. L., Rocroi, C., Brand, R. J., & Brown, E.) [Serial No. 262].
Imai, M., Li, L., Haryu, E., Okada, H., Hirsh-Pasek, K., Golinkoff, R. M., et al (2008). Novel noun and verb learning in Chinese-, English-, and Japanese-speaking children. *Child Development, 79*, 979–1000.
Jackendoff, R. (1983). *Semantics and cognition*.Cambridge, MA: MIT Press.
Konishi, H., Stahl, A., Golinkoff, R. M., & Hirsh-Pasek, K. (2016). Individual differences in non-linguistic event categorization predict later motion verb comprehension. *Journal of Experimental Child Psychology, 151*, 18–32.
Langacker, R. W. (1987). Nouns and verbs. *Language, 63*, 53–94.
Maguire, M. J., Hirsh-Pasek, K., & Golinkoff, R. M. (2006). A unified theory of verb learning: Putting verbs in context. In K. Hirsh-Pasek & R. M. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 364–391). New York: Oxford University Press.
Maguire, M. J., Hirsh-Pasek, K., Golinkoff, R. M., Imai, M., Haryu, E., Vanegas, S., ... Sanchez-Davis, B. (2010). A developmental shift from similar to language specific strategies in verb acquisition: A comparison of English, Spanish, and Japanese. *Cognition, 114*, 299–319.
Mandler, J. M. (1992). How to build a baby II: Conceptual primitives. *Psychological Review, 99*, 587–604.
Mandler, J. M. (1996). Preverbal representation and language. In P. Bloom, M. Peterson, L. Nadel, & M. Garrett (Eds.), *Language and space* (pp. 365–384). Cambridge, MA: MIT Press.
Mandler, J. M. (2004). *The foundations of mind: Origins of conceptual thought*.New York: Oxford University Press.
Mandler, J. M., & Cánovas, C. P. (2014). On defining image schemas. *Language and Cognition, 6*, 510–532.
Markman, E. M. (1991). *Categorization and naming in children: Problems of induction*.Cambridge, MA: MIT Press.
McDonough, L., Choi, S., & Mandler, J. M. (2003). Understanding spatial relations: Flexible infants, lexical adults. *Cognitive Psychology, 46*, 229–259.
Murphy, G. L. (2010). What are categories and concepts? In D. Mareschal, P. C. Quinn, & S. Lea (Eds.), *The making of human concepts* (pp. 75–98). Oxford, UK: Oxford University Press.
Nelson, K. (1986). *Event knowledge: Structure and function in development*.Hillsdale, NJ: Lawrence Erlbaum.
Oakes, L. M., & Rakison, D. H. (2003). Issues in the early development of concepts and categories. In D. H. Rakison & L. M. Oakes (Eds.), *Early category and concept development: Making sense of the blooming, buzzing confusion* (pp. 3–23). New York: Oxford University Press.
Parish, J., Hennon, E., Hirsh-Pasek, K., Golinkoff, R. M., & Tager-Flusberg, H. (2007). Children with autism illuminate the role of social intention in word learning. *Child Development, 78*, 1265–1287.
Pruden, S. M., Göksun, T., Roseberry, S., Hirsh-Pasek, K., & Golinkoff, R. M. (2012). Find your manners: How do infants detect the invariant manner of motion in dynamic events? *Child Development, 83*, 977–991.
Pruden, S. M., Roseberry, S., Göksun, T., Hirsh-Pasek, K., & Golinkoff, R. M. (2013). Infant categorization of path relations during dynamic events. *Child Development, 84*, 331–345.
Pulverman, R., Golinkoff, R. M., Hirsh-Pasek, K., & Buresh, J. S. (2008). Infants discriminate manners and paths in non-linguistic dynamic events. *Cognition, 108*, 825–830.
Pulverman, R., Song, L., Pruden, S., Golinkoff, R. M., & Hirsh-Pasek, K. (2013). Infants' attention to manner and path: Foundations for learning relational terms. *Child Development, 84*, 241–252.
Quinn, P. C. (1994). The categorization of above and below spatial relations by young infants. *Child Development, 65*, 58–69.
Quinn, P. C. (2002). Early categorization: A new synthesis. In U. Goswami (Ed.), *Blackwell handbook of childhood cognitive development* (pp. 84–101). Oxford, UK: Blackwell.
Quinn, P. C. (2006). On the emergence of perceptual organization and categorization in young infants: Roles for perceptual process and knowledge access. In L. Balter & C. S. Tamis-LeMonda (Eds.), *Child psychology: A handbook of contemporary issues* (2nd ed., pp. 109–131). New York: Psychology Press.
Quinn, P. C. (2007). On the infant's prelinguistic conception of spatial relations: Three developmental trends and their implications for spatial language learning. In J. M. Plumert & J. P. Spencer (Eds.), *The emerging spatial mind* (pp. 117–141). New York: Oxford University Press.
Quinn, P. C., Cummins, M., Kase, J., Martin, E., & Weissman, S. (1996). Development of categorical representations for above and below spatial relations in 3- to 7-month-old infants. *Developmental Psychology, 32*, 642–650.
Quinn, P. C., & Intraub, H. (2007). Perceiving "outside the box" occurs early in development: Evidence for boundary extension in three- to seven-month-old infants. *Child Development, 78*, 324–334.
Quinn, P. C., Polly, J. L., Furer, M. J., Dobson, V., & Narter, D. B. (2002). Young infants' performance in the object-variation version of the above–below categorization task: A result of perceptual distraction or conceptual limitation? *Infancy, 3*, 323–347.

Roseberry, S., Göksun, T., Hirsh-Pasek, K., & Golinkoff, R. M. (2012). Carving categories in a continuous world: Preverbal infants discriminate categorical changes before distance changes in dynamic events. *Spatial Cognition and Computation, 12*, 231–251.
Roseberry, S., Richie, R., Hirsh-Pasek, K., Golinkoff, R. M., & Shipley, T. (2011). Babies catch a break: 7- to 9-month-olds track statistical probabilities in continuous dynamic events. *Psychological Science, 22*, 1422–1444.
Sharon, T., & Wynn, K. (1998). Individuation of actions from continuous motion. *Psychological Science, 9*, 357–362.
Snedeker, J., & Gleitman, L. R. (2004). Why is it hard to label our concepts? In D. G. Hall & S. R. Waxman (Eds.), *Weaving a lexicon* (pp. 257–293). Cambridge, MA: MIT Press.
Stahl, A., Romberg, A., Roseberry, S., Golinkoff, R. M., & Hirsh-Pasek, K. (2014). Infants segment continuous events using transitional probabilities. *Child Development, 85*, 1821–1826.
Talmy, L. (1985). Lexicalization patterns: Semantic structure in lexical forms. In T. Shopen (Ed.), *Language typology and syntactic description* (pp. 57–149). New York: Cambridge University Press.
Tomasello, M. (1995). Pragmatic contexts for early verb learning. In M. Tomasello & W. E. Merriman (Eds.), *Beyond the names for things: Young children's acquisition of verbs* (pp. 115–146). Hillsdale, NJ: Lawrence Erlbaum.
Verschoor, S. A., Paulus, M., Spape, M., Biro, S., & Hommel, B. (2015). Sequential-action representation in infants: Evidence for concurrent-activation models. *Cognition, 138*, 64–78.
Waxman, S. R. (2003). Links between object categorization and naming: Origins and emergence in human infants. In D. H. Rakison & L. M. Oakes (Eds.), *Early category and concept development: Making sense of the blooming, buzzing confusion* (pp. 213–214). New York: Oxford University Press.
Woodward, A. L. (1998). Infants selectively encode the goal object of an actor's reach. *Cognition, 69*, 1–34.
Wynn, K. (1996). Infants' individuation and enumeration of actions. *Psychological Science, 7*, 164–169.
Zheng, M., & Goldin-Meadow, S. (2002). Thought before language: How deaf and hearing children express motion events across cultures. *Cognition, 85*, 145–175.