Prelinguistic Foundations of Verb Learning: Infants Discriminate and Categorize Dynamic Human Actions

Lulu Song[1], **Shannon M. Pruden**[2], **Roberta Michnick Golinkoff**[3], and **Kathy Hirsh-Pasek**[4]

[1]Brooklyn College, the City University of New York

[2]Florida International University

[3]University of Delaware

[4]Temple University

Abstract

Action categorization is necessary for human cognition and 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.

Keywords

categorization; discrimination; human actions; verb learning; event perception

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 it 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 et al., 2002; Golinkoff & Hirsh-Pasek, 2008). While 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 paper 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 as 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 respond to their class membership or commonalities rather than their uniqueness (Bruner, Goodnow, & Austin, 1956). Similarly, Murphy (2010) defines 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" (p. 3, Oakes & Rakison, 2003). 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). Further, humans can jump, animals can jump, and even inanimate objects can jump, as 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 upon their ability to perceive both the commonality and the 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 et al., 2002; Golinkoff & Hirsh-Pasek, 2006).

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 "imageschemas" (e.g., path, containment, up-down, and 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, Pruden et al., 2013, for work with animated actions), with these studies generally finding that infants categorize nonlinguistic actions and events between 10- and 15-months of age. Notably, these are the same ages 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 around 10 months; *hug* around 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-old infants 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-old infants 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 parse continuous action into individual actions for 9- to 12-month-old infants (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, 1991; Talmy, 1985). Talmy (1985) proposed that the linguistic representation of motion events includes several key components including, among others, 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*). 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 versus brushing hair, even when the actions are 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 like 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, utilizing animated, cartoon-like events. Building on Pulverman et al.'s discrimination work (2008; 2013), Pruden and colleagues (Pruden et al., 2012; Pruden et al., 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) while the other 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 et al. (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 homogenous 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 present studies expand and improve upon Pruden et al.'s (2012) categorization work in three ways. First, rather than asking infants to simply abstract the manner performed by the same agent, we present infants with five human actors performing the same manner of motion, marching, along five different paths. Thus, the stimuli instantiate the manner category with much greater variability than previous studies. Second, all the actions take place in a natural setting—in front of a building—approximating actions infants encounter in real life. Finally, the use of multiple actors enables 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; Hirsh-Pasek & Golinkoff, 1996; Golinkoff, Ma, Song, & Hirsh-Pasek, 2013). 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 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 et al. (2013) demonstrated that English-learning 7-month-olds detected manner and path changes in dynamic, animated motion events. In Study 1, we ask 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: (1) a path variation (e.g., Mike marches across vs. Mike marches in a circle) and (2) an actor variation (e.g., Mike marches across vs. Kate marches across).

Method

Participants—Twenty-seven 10- to 12-month-old infants were included in the final sample ($M = 11.52$, $SD = 1.00$; 14 males, 13 females). 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 Northeast United States. Six (18%) additional infants were tested but not included because of fussiness ($n = 2$), parental interference ($n = 1$; see *Procedure* below for details), low attention (watched for less than 50% of the time; $n = 1$), experimenter error/coding issues ($n = 1$), and side bias—attention to

one side of the screen across the test trials was more than 75% ($n = 1$) (see Golinkoff et al., 2013).

Apparatus—The visual stimuli were presented on a large, 44-inch television screen. When displayed full-screen, the image covered an area of 57.5 cm × 76 cm. Music was played through the builtin 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 utilizing 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 each actor's identity.

The exemplars not only differed in the path of the actor and the appearance of the actor, but also in *how* each actor marched along each path; the way each actor performed the manner of marching varied. For example, the actors differed in how high they lifted their thighs and arms when marching. Further, the same actor 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 motion. As a result, each actor had 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-subjects conditions. Participants were randomly assigned to one of these 14 between-subjects conditions.

Procedure—Infants sat on a parent's lap in front of a large television screen and watched a short movie in a dimly lit room. The distance between the 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.

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) respectively. Test trials were also separated by the intertrial stimulus. In 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 sides 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 (1) infants fixated on the screen during the familiarization trials; and (2) their fixation 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 with 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 above .50 meant that the infant looked at the novel event longer than 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, p's > .35). Thus, data were collapsed across these variables in further analyses.

Familiarization Phase—On average, infants fixated on the screen almost the entire time during the first familiarization trial (M = .99, SD = .04). In 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 to the last familiarization trials ($p < .001$), 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 in this trial and thus were not included; see Figure 1. Eighteen out of 25 (72%) infants showed a preference for the novel event, which was significantly higher than would be observed by chance ($\chi^2 = 4.84$, $p = 0.028$). Taken together, these results show that infants looked significantly longer at the novel event over the familiar event in the path discrimination trial.

Actor discrimination trial: Infants' looking times for the novel and the 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 over 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, $t(25) = 1.39$, $p = .18$, $d = .26$; one infant did not attend to the screen in this trial and was not included; see Figure 1). Sixteen out of 26 infants (62%) showed a novelty preference, which was not significantly different than would be expected by chance ($\chi^2 = 1.39$, $p = 0.239$).

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 argued (2007), 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 in the first and second halves of the actor discrimination trial (i.e., first 6 s versus 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 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 Figure 2). However, neither the comparison of looking times to the novel ($M = 2.88$, $SD = 1.92$) and the familiar events ($M = 2.23$, $SD = 1.76$) ($t(26) = 0.99$, $p = .333$, $d = 0.19$) nor the comparison of PLN ($M = .55$, $SD = .33$) with chance level ($t(24) = 0.82$, $p = .421$, $d = 0.15$) showed significant difference in 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 within the first half of the test trial, suggesting that they did indeed discriminate among the actors. While these results are post-hoc in nature, the lack of significant preference in the second half of the test trial suggests that differences among actors may not be salient enough to the preverbal infant 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, Gogate & Ruiz, 2002; Bahrick & Newell, 2008). Alternatively, a quickly subsiding novelty response, like 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 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: (1) a variety of different stimuli from a single action category must be presented during the familiarization phase, and (2) 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, utilized 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, etc.). Second, at test they 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 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, then they should display a significant preference for one of the events at test. If infants failed to categorize, both actions during the test phase should look novel and not elicit any differential looking patterns. This exact design and set-up 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 (salience) and after (test) 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 with 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—Twenty-eight 10- to 12-month-old infants ($M = 11.29$, $SD = 0.99$; 13 males, 15 females) 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 (31%) infants 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" ($n = 2$), experienced experimental error ($n = 3$), or 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 grey 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 in 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 in the first and second halves of the familiarization phase were randomly determined for each of the four between-subjects 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.

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 (FF) was calculated in the same way as in Study 1. Because all 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, thus 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 the 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 the 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 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 (F's < 3.07, p's > .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 over 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 equally interesting.

Familiarization Phase—We conducted a repeated-measures ANOVA with infants' FF in each familiarization trial as the within-subjects dependent variable. A significant main effect of FF emerged suggesting significant differences among the FF's across familiarization trials, $F(7, 189)$ = 5.54, p < .001, η_p^2 = .17. Notably, there was a significant linear trend, $F(1, 27)$ = 8.07, p = .008, η_p^2 = .23, as well as a significant cubic trend of infants' FF, $F(1, 27)$ = 7.79, p = .01, η_p^2 = .22. This significant cubic trend was explained by infants' initial decrease in FF in the first four trials, a slight increase in their attention in the next three trials, and a final decrease in the last trial (see Figure 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 in 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 over 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 in the salience

and test phases are plotted in Figure 4. Furthermore, of the 28 infants tested, 21 (or 75%) showed a preference for the out-of-category event during the test phase ($\chi^2 = 7.00$, $p = 0.008$). 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-months infants 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 a 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 "novel" to infants afterwards, despite the appearance of the action once in the salience trial.

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, as 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 rather than the latter view. 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 study, 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, as 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 et al. (2013). In this 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 paper 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 et al. (2012) changed either the relationship between the figure and the ground (i.e., over versus 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 unlikely based on evidence from earlier studies.

Second, did infants form the category in 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 have probably not seen many marching instances in their short lives, although it is possible some infants have had prior exposure (e.g., watching parade on the street or media); nor can they carry out a marching action. From a linguistic standpoint, there is little reason to believe that these infants understood the word *march*; nor at this age do they have many other action words in their small receptive vocabularies. On average, the 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 the 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 10- to 12-month-olds may already possess a category of "walking," as 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 the infants comprehend *walk* at 13 months (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. However, 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 while hopping instances were excluded. Crucially, the experiment demonstrated that infants possessed the cognitive abilities required for forming categories of actions. Thus, the third question is, how did infants achieve categorization of the marching actions?

Compared to prior action categorization research (e.g., Pruden et al., 2012), our stimuli were more realistic, utilizing 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 to 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); 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 or 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 while the other 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, for example, 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 et al. (2011) found that although both the 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 of age. 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 to 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, cause, etc. (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; Göksun et al., 2010; Golinkoff et al., 2002; Golinkoff & Hirsh-Pasek, 2008; Tomasello, 1995; Snedeker & Gleitman, 2004). 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; Maguire et al., 2010; McDonough, Choi, & Mandler, 2003; Hespos & Spelke, 2004). 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 to 12 months 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 in the third year of life (Konishi, Stahl, Golinkoff, & Hirsh-Pasek, under review). Furthermore, that relationship appears to be independent of the number of nouns children have at that later time. Given the relative difficulty 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' ability to discriminate among and categorize across *dynamic actions*.

Thus, the research presented in the current paper represents a unique contribution to the literature on infants' categorization and on the precursors to learning names for actions.

Acknowledgments

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Highlights

- We examined infants' prelinguistic foundations of verb learning.

- Event processing was examined in a nonlinguistic preferential looking paradigm.

- Infants discriminated between marching actions across different paths and actors.

- Infants categorized marching actions across different paths and actors.
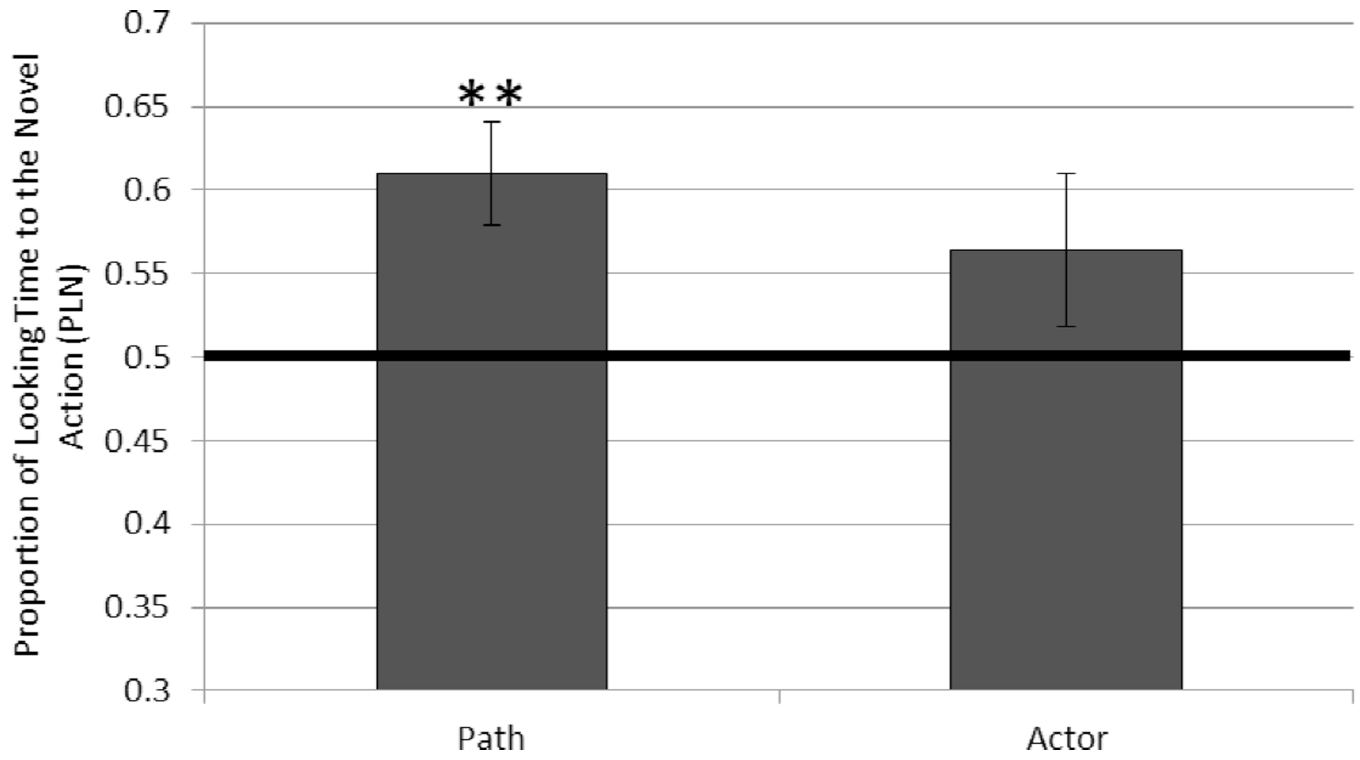
Figure 1.
Study 1: Infants' proportion of looking time to the novel action (PLN) in the path and actor discrimination trials at test. Error bars represent standard errors. **$p < .005$
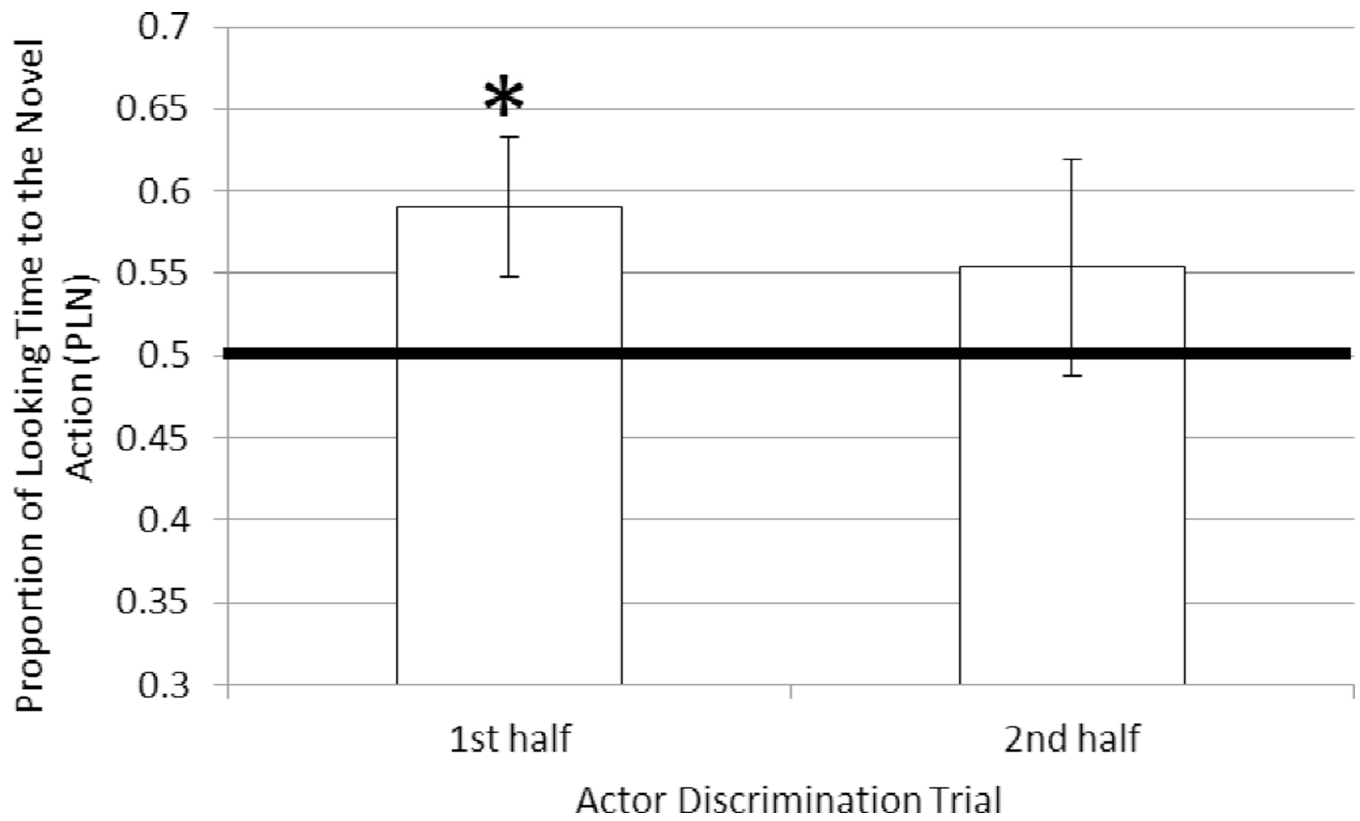
Figure 2.
Study 1: Infants' proportion of looking time to the novel action (PLN) in first and second halves of the actor discrimination trial at test. Error bars represent standard errors. $*p < .05$
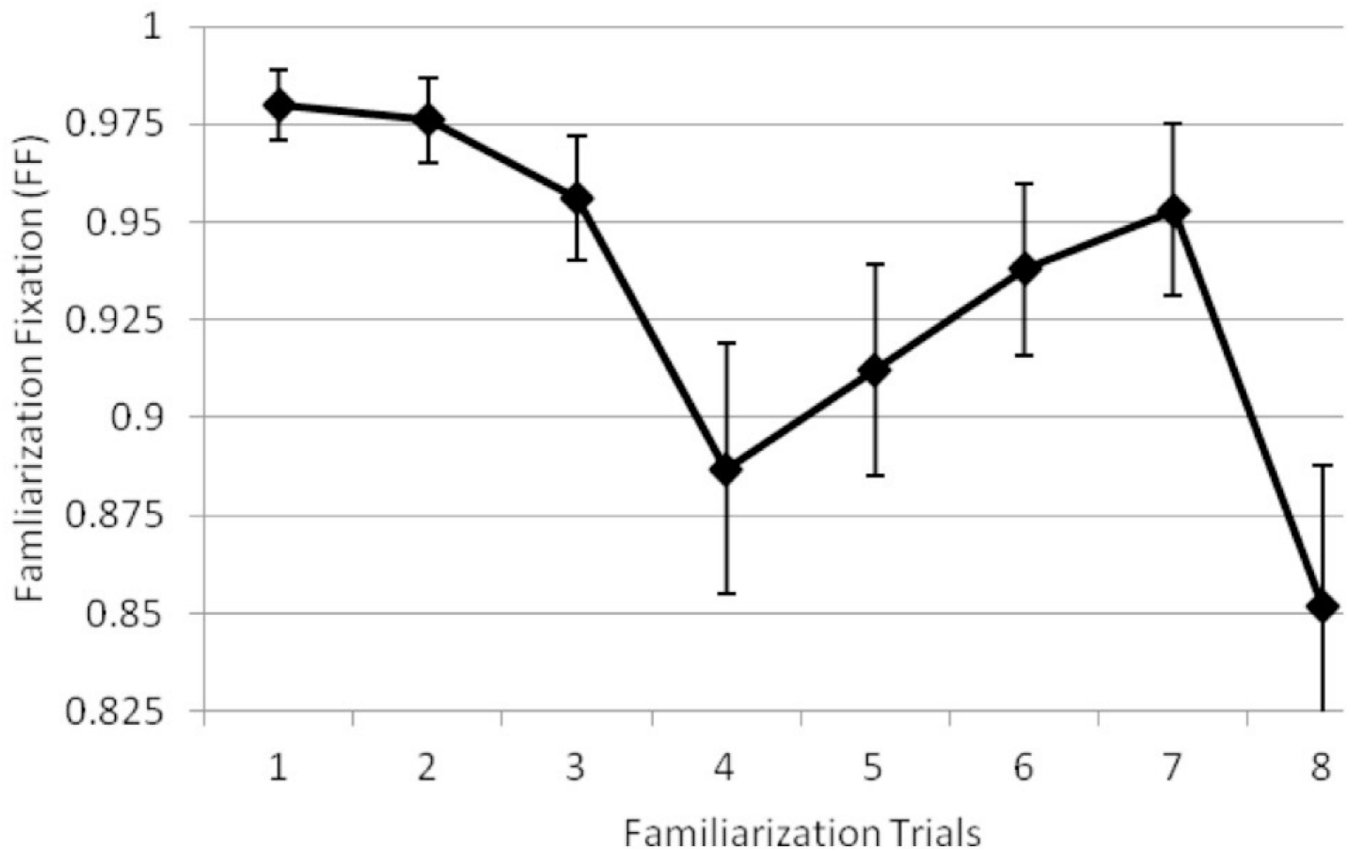
Figure 3.
Study 2: Infants' attention (FF) in the familiarization phase. Error bars represent standard errors.
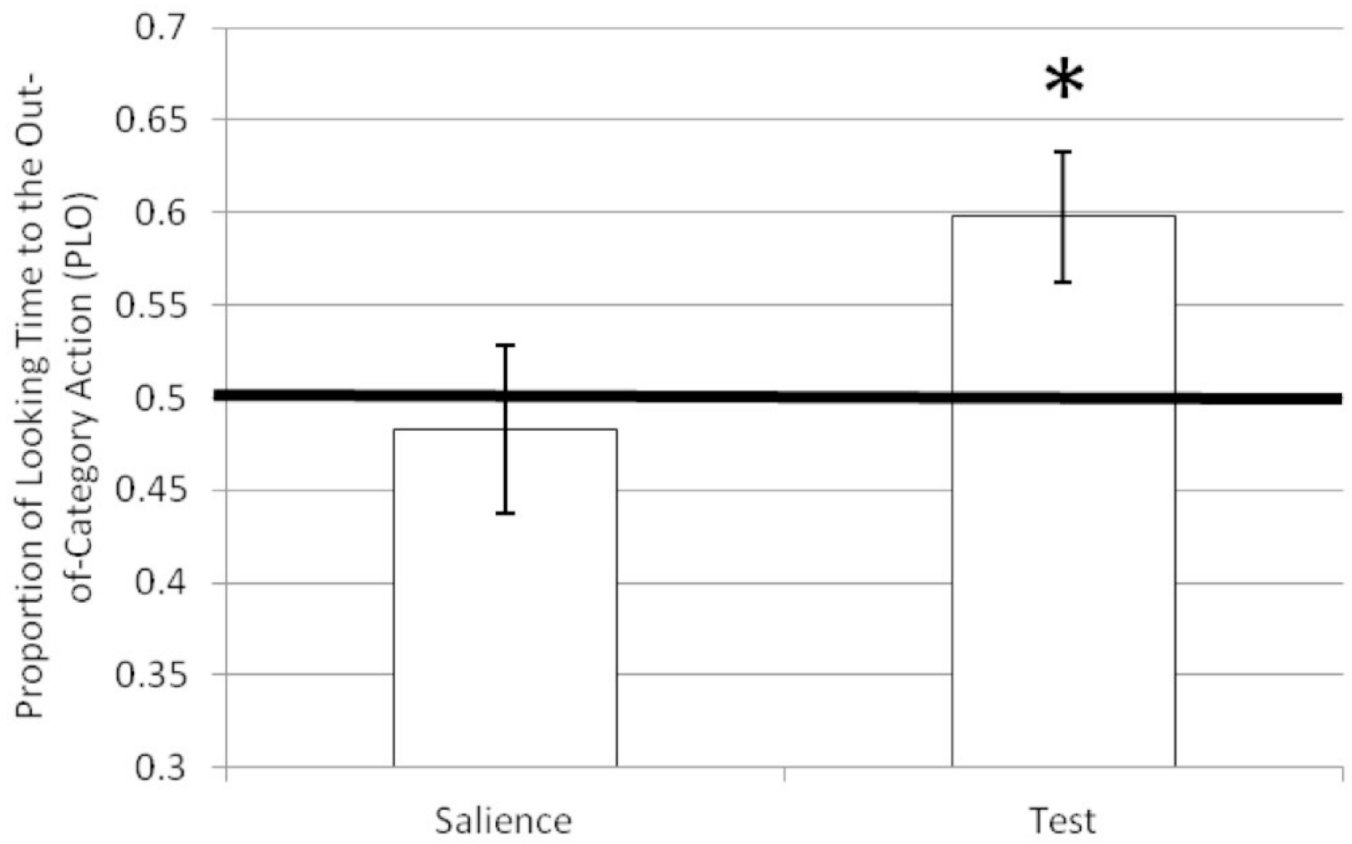
Figure 4.
Study 2: Infants' proportion of looking time to the out-of-category action (PLO) in the salience and test phases. Error bars represent standard errors. *$p < .05$

Table 1

Descriptions of the Action Stimuli Presented in Studies 1 and 2

Five Different Paths	Examples of Actions and Actors	Descriptions
"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 s/he reaches the marked end of the path, without any pause, s/he 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) counter-clockwise 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 6th stair from the bottom, marches (or hops with both legs) down step by step until s/he reaches the bottom step. Then s/he turns around and marches (or hops) back up to the starting step.

Table 2

Study 1: Design of the Discrimination Movies

	Visual Stimuli		**Duration**
Familiarization Trials 1–10	A marches across		6 s per trial
Test 1 (path)	A marches *across*	A marches *in a fixed position*	12 s
Test 2 (actor)	*B* marches across	*A* marches across	12 s
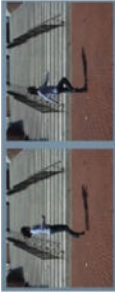
Table 3

Study 2: Design of the Categorization Movies and the Action Exemplars

		Visual Stimuli	Examples	Duration
Salience		A hops across / A marches across		12 s
Familiarization	**Trials 1–4**	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 5–8	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.