CHILD DEVELOPMENT

Child Development, January/February 2013, Volume 84, Number 1, Pages 241–252

Preverbal Infants' Attention to Manner and Path: Foundations for Learning Relational Terms

Rachel Pulverman
Delaware State University

Lulu Song
Brooklyn College, City University of New York

Kathy Hirsh-Pasek
Temple University

Shannon M. Pruden
Florida International University

Roberta M. Golinkoff
University of Delaware

In the world, the manners and paths of motion events take place together, but in language, these features are expressed separately. How do infants learn to process motion events in linguistically appropriate ways? Forty-six English-learning 7- to 9-month-olds were habituated to a motion event in which a character performed both a manner and a path, and then tested on events that changed the manner, path, both, or neither. Infants detected each type of change, but only the girls showed evidence of processing manner and path as independent features. This gender difference provides clues about the universal development of manner and path concepts from more basic perceptual skills. Results have implications for how representations of linguistically relevant semantic elements develop conceptually.

Unraveling how children learn verbs and other dynamic relational terms (e.g., *run, approach, into*) is critical to understanding language acquisition. Verbs not only allow us to express actions, but also specify the syntactic framework that enables us to communicate event structure such as who did what to whom. However, verb learning poses something of a paradox for researchers: On the one hand, as compared to nouns, verbs seem relatively difficult for children in most languages (Bornstein et al., 2004; Caselli, Bates, Casadio, & Fenson, 1995; Imai et al., 2008; but see Choi, 1998; Tardif, 1996). On the other hand, even in languages in which verb learning is difficult, some verbs are present in children's earliest vocabularies (Choi, 1998; Choi & Bowerman, 1991; Choi & Gopnik, 1995; Fenson et al., 1994; Naigles, Hoff, & Vear, 2009; Nelson, 1989; Tardif, 1996). As Mandler (1996) wrote, "The preverbal [conceptual] system forms the foundation on which language rests, and it constrains what is learnable" (p. 365). In this article, we explore preverbal infants' processing of dynamic motion. Specifically, we ask whether English-reared 7- to 9-month-olds can detect the two dynamic features of events that motion verbs most commonly express—manner and path—and whether they process those features independently of one another.

Together but Separate: Manner and Path in Events Versus in Language

Manner and path are two features of event structure of particular interest to studying the conceptual roots of motion verbs. Path refers to the trajectory of an entity with respect to some reference point (e.g., *out* of a box, *approaching* a

This research was part of the first author's dissertation at the University of Delaware, and was funded by NSF Grants SBR9601306 and SBR9615391 to the fourth and fifth authors. The writing of this article was also supported by NIH NRSA Training Grant T32 HD007109 to Developmental Psychology at the University of Michigan, a Chinese Academy of Sciences Research Fellowship for International Young Researchers to the first author, and NSF HBCU-RISE Award HRD 0833148 to Leonard Davis. We thank everyone at the University of Delaware's Infant Language Project and Temple University's Infant Lab for their invaluable contributions. We offer our deepest appreciation to all of the parents and infants who participated in the project.

Correspondence concerning this article should be addressed to Rachel Pulverman, Department of Psychology, Delaware State University, 1200 North DuPont Highway, Dover, DE 19901. Electronic mail may be sent to rpulverman@desu.edu.

 0009-3920/2013/8401-0019
DOI: 10.1111/cdev.12030

stranger). Manner refers to how an action is carried out (e.g., *walking, twisting*; Talmy, 1985) and captures a dynamic relation between an entity's internal parts (e.g., the verb *kick* describes the motion of a person's leg in relation to the rest of their body; Kersten, 1998). Both of these motion features are represented in all of the world's languages and thus appear to be universal concepts (Jackendoff, 1983). Interestingly, there is a mismatch between how manners and paths occur in the world and how they are represented in language. In the world, manners and paths nearly always occur together—for an object to traverse a path, it must be moving in some manner, and many manners naturally propel entities along a path (e.g., *walking, rolling, sliding*). In contrast, language separates manner from path, expressing them via separate words (e.g., *The baby crawled*$_{\text{MANNER}}$ *across*$_{\text{PATH}}$ *the floor*). The separation of these features is so linguistically fundamental that languages are classified typologically based on how they tend to encode manner and path (e.g., Slobin, 2004; Talmy, 1985). For example, in Spanish, to describe an event in which a woman ran as she exited a house, one would most likely say, *Una mujer salió*$_{\text{PATH}}$ *de la casa corriendo*$_{\text{MANNER}}$ ("A woman exited$_{\text{PATH}}$ the house running$_{\text{MANNER}}$"). Here, as in other "verb-framed" languages, the path is expressed by the verb, with manner expressed *optionally* via satellites such as adverbs. In "satellite-framed" languages, like English, path is usually encoded by satellites such as particles or prepositions, leaving the verb to express manner. The event above would typically be expressed as *A woman ran*$_{\text{MANNER}}$ *out*$_{\text{PATH}}$ *of the house*. Because path and manner are universally expressed, and because they receive differential emphasis among different language groups, the study of how these dynamic event features are processed by infants offers a potential toehold into how infants' event representations interact with their word learning.

Theoretical Consensus: The Concepts Should Be Available

A number of theories suggest that we should expect infants to be sensitive to manner and path and to process them as separate, independent event features. As Mandler (1992, 1996, 2004) notes, there appear to be striking parallels between infants' cognitive processing and the distinctions made by language. The cross-linguistic universality of manner and path as lexicalized semantic elements suggests that these concepts are fundamental to humans and may be present very early. Manner and path specifically have both been touted as "basic ontological categories" of conceptual structure and have been called "primitives" (Jackendoff, 1983; Langacker, 1987). Language acquisition researchers have also argued that infants are conceptually equipped to learn verbs and propose that the difficult part of verb learning is determining *which* concept should be mapped to any given word (Gentner, 1982; Gillette, Gleitman, Gleitman, & Lederer, 1999).

Yet, there are several reasons we cannot simply stipulate that infants process the manners and paths of motion events in terms of the semantic components that support verb learning. First, very little is known about manner and path processing even in adults (but see Kersten & Billman, 1997; Kersten et al., 2010; Wu, Morganti, & Chatterjee, 2008), although adults do express these semantic elements in their language. Second, there is little work on infants' understanding of the dynamic features of events. In fact, the study of event perception is just beginning (see Shipley & Zacks, 2008) and, until recently, we knew little about how infants decompose complex visual events into features that are linguistically relevant, such as manner, path, figure, and ground. In addition, recent research on English and Mandarin Chinese suggests that conceptual factors influence the ease with which infants and toddlers learn verbs. Ma, Golinkoff, Hirsh-Pasek, McDonough, and Tardif (2009) found that more imageable verbs (i.e., those that more readily evoke a mental image) tend to be acquired earlier than less imageable verbs. Similarly, Pulverman and colleagues (Pulverman, Rohrbeck, Chen, & Ulrich, 2008; Pulverman, Tardif, Rohrbeck, & Chen, 2010) and Ma (2009) report that verbs that are more specific in meaning are more easily learned. This evidence suggests that part of the challenge of verb learning may be the difficulty of the concepts themselves. Finally, it has been argued that some spatial concepts, including path, may not be fully developed prior to learning the corresponding words in one's language. Rather, infants may construct these concepts *in the course of* their word learning; the concepts may be built as infants detect the similarities and differences between different events to which the same word is applied (Choi & Bowerman, 1991; Wynn, 1992). For example, Wynn's (1992) research on children's acquisition of number words suggests that children learn to apply the concept of numerosity after they have acquired number words and may be using the number words to ascertain numerosity. Perhaps, then, infants learn that manner can be extracted from composite events as a result of hearing a verb like *run* used to describe running

out of a house, running across a street, and running around a tree. One way to evaluate this theory is to examine whether infants are able to separate conceptual elements like manner and path from events *prior* to learning verbs.

Infants' Processing of Event Features

In recent years, research has begun to address infants' processing of a number of linguistically relevant event features. The most extensively studied features pertain to spatial verbs and prepositions. Choi and colleagues (Choi, 2006; Choi, McDonough, Bowerman, & Mandler, 1999; McDonough, Choi, & Mandler, 2003) and Casasola and colleagues (Casasola, 2008; Casasola, Bhagwat, & Ferguson, 2006; Casasola & Cohen, 2002) have conducted studies examining infants' ability to recognize when objects were placed into particular spatial relations. The relations tested corresponded to the English prepositions *in* (containment) and *on* (support) and the Korean verb *kkita* (meaning "to put tight-fitting," with no distinction between containment and support). Results suggest that preverbal infants can form categories of containment and support. Even English-reared 5-month-olds are sensitive to the Korean contrast of tight- versus loose-fit (Hespos & Spelke, 2004). Thus, at least some relational features of motion events are detected and represented prior to their corresponding lexical terms.

Studies examining infants' processing of the people, objects, and settings in dynamic motion events also provide evidence that events are represented similarly in infants' minds and in language. Göksun et al. (Göksun, Hirsh-Pasek, & Golinkoff, 2009; Göksun et al., 2011; also see Bornstein, Mash, & Arterberry, 2011) tested English-learning infants' sensitivity to figure (the prominent person or object undergoing motion) and ground (the reference point for the figure's path) in motion events. They familiarized infants to a scene in which a figure crossed a ground (e.g., a woman crossing a street) and tested their discrimination of figure changes (e.g., a man or a child crossing the street) and ground changes (e.g., the woman crossing a railroad track or a field). At 10–12 months, infants detected changes of figure, and at 13–15 months they detected changes of ground in dynamic events. Interestingly, infants were particularly sensitive to ground distinctions that varied on rather subtle geometric properties like whether they extended in a line (such as a street or railroad track) or in a plane (such as a field or tennis court). Although this categorical distinction is irrelevant in English, Japanese uses different verbs for crossing these different types of grounds. These results parallel those of Hespos and Spelke (2004), suggesting that young infants can represent distinctions in event features that may prepare them to learn *any* language, not just their own.

Wagner and Carey (2005) and Lakusta, Wagner, O'Hearn, and Landau (2007) investigated another type of ground distinction—the distinction between source (i.e., the origin of a path) and goal (i.e., its destination). They found that 12-month-old infants are able to detect both source changes and goal changes, but when both sources and goals are present, they are more likely to notice goal changes than source changes. This finding parallels the linguistic tendency to preferentially express goals over sources (Lakusta & Landau, 2005).

Given that preverbal infants and infants just breaking into verb learning are sensitive to several features of event structure relevant to learning verbs and other relational terms, they might also be able to detect manners and paths in motion events. However, manner and path differ from other event features that have been studied in important ways. Although the containment versus support versus tight-fit studies all utilized dynamic events showing a hand that placed objects into particular spatial relations, the crucial distinctions between containment and support or tight- and loose-fit could be made based on the *static endpoints* of the events. While figures, grounds, sources, and goals can only be identified in the context of motion (e.g., in *Jimmy ran to the tree;* the tree is the goal because it is the destination of Jimmy's motion), these constructs identify people or objects rather than properties of motion itself. Thus, very little is known about how young infants process the *dynamic* features of motion.

Manner and Path Detection in Older Infants

As a first step in understanding infants' processing of manner and path, Pulverman, Golinkoff, Hirsh-Pasek, and Sootsman Buresh (2008) investigated whether 14- to 17-month-old English- and Spanish-learning infants could discriminate between paths and between manners in simple, animated motion events involving a starfish figure moving with respect to a stationary ball (the ground object; see Figure 1). Infants were first habituated to an event with both a manner and a path (e.g., the starfish spinning past the ball), and then tested (within subjects) on events with manner and/or path changes. Results showed that infants in both

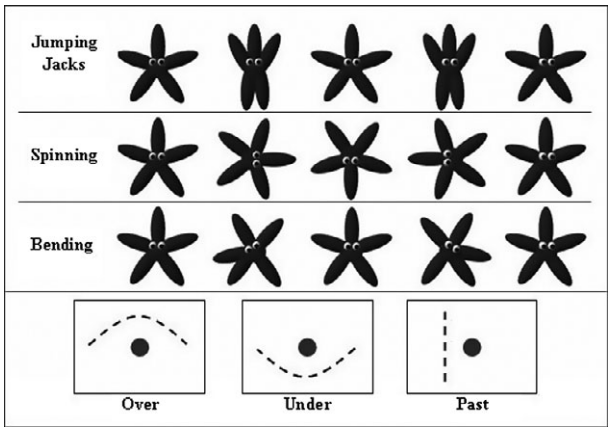

Figure 1. Manners and paths used in stimuli.
Note. Although illustrated as a series of static postures, the starfish performed the manners as continuous motions. (Fig. 5.1 from the chapter "Conceptual Foundations for Verb Learning: Celebrating the Event" by R. Pulverman et al., p. 142 from *Action Meets Word: How Children Learn Verbs*, edited by K. Hirsh-Pasek and R. M. Golinkoff (2006). By permission of Oxford University Press, Inc.)

language groups were able to detect changes of both manner and path.

Casasola, Hohenstein, and Naigles (2003) presented preliminary evidence that younger, 10-month-old English-learning infants can discriminate manners and paths in videos of simple, live-action scenes (a girl crawling or skipping toward or away from a bush) as well. However, it is possible that the infants in their study could have distinguished the paths based on the static start- or endpoints of the events (far from the bush or next to it) or distinguished the manners based on the actor's constant posture throughout her enactment (upright for skipping, but on all fours for crawling). Thus, it remains unclear whether infants below 14 months are able to process the *dynamic* features of events. The findings that 14- to 17- and possibly 10-month-olds distinguish between events with differing manners or paths suggest that they observe the world in language-relevant ways. However, by 14 months, and arguably by 10 months, infants have already begun to learn relational terms, including some verbs and prepositions (Fenson et al., 1994). It remains unclear whether infants must be able to detect language-relevant event features as a prerequisite to learning their earliest relational terms, or whether the word-learning process helps infants find the features in the first place. Thus, empirical evidence is needed to determine whether preverbal infants detect changes of manner and path.

Another issue that needs to be explored is whether infants recognize that dynamic events are made up of separable, simultaneously occurring parts. Verbs do not label composite events. Rather, language separates events into component features and lexicalizes these features in different words in a sentence (e.g., *ran out*). Therefore, to map verb labels onto their corresponding concepts, infants must treat manner and path (and other event components) as independent features. No previous research has addressed whether infants have this ability (but see Pulverman, Hirsh-Pasek, Golinkoff, Pruden, & Salkind, 2006, for preliminary findings). However, the adult literature gives us an idea of what independent feature processing should look like. In studies of adult cognition, the number of features involved influences processing time. For example, Treisman and Gelade (1980) found that adults detected a target stimulus in an array equally quickly regardless of the number of distractors when only a single feature was needed to identify the target. In contrast, target detection slowed linearly as the number of distractors increased when multiple features were required to identify the target, suggesting that participants had to process the separate features of each stimulus one at a time. The results of these and other studies suggest that tasks involving a single visual feature invoke *parallel* processing, whereas tasks requiring the use of a conjunction of independent features invoke *serial* processing (e.g., Treisman & Gelade; Lobaugh, Cole, & Rovet, 1998). Evidence that infants process manner and path serially would suggest that they are sensitive to manner and path as independent features of events.

In addition, it is important to investigate the role of gender in event processing. Boys tend to outperform girls on a number of spatial and relational tasks (Levine, Huttenlocher, Taylor, & Langrock, 1999; Linn & Petersen, 1985; Maccoby & Jacklin, 1974; Quinn & Liben, 2008; Voyer, Voyer, & Bryden, 1995), including the production of specific spatial and relational terms (Pruden & Levine, 2011). Girls, however, are thought to have a general language advantage, with research showing that they comprehend and produce more overall word types than boys and that they are ahead of boys in their grammatical development (Bauer, Goldfield, & Reznick, 2002; Bornstein, Hahn, & Haynes, 2004; Fenson et al., 1994; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991). As manner and path lie at the intersection of space and language, the potential effects of gender must be taken into account before drawing general conclusions about infants' processing of dynamic events.

The current research addresses three questions that will further our understanding of infants' processing of the dynamic features of motion events.

First, do 7- to 9-month-old infants notice manner and path in motion events? Second, do they treat manner and path as *independent* features of events, or is the detection of manner and path changes best characterized as simply noticing that the event is different *as a composite*? And third, how (if at all) do boys and girls differ in their processing of manner and path?

This experiment builds on the work of Pulverman, Golinkoff, et al. (2008). Seven- to nine-month-olds were habituated to a scene in which an animated starfish moved in a particular manner along a particular path. They were then tested to determine what types of distinctions they could make among four types of test events: control (identical to the habituation event), path change, manner change, and both (path and manner) change. If it is true, as some contend (e.g., Jackendoff, 1983; Mandler, 1992, 2004), that manner and path are conceptual primitives, then (using Mandler's notion of conceptual primitives as basic concepts that can be constructed from perceptual information) these young infants may show signs of treating manner and path as *independent* features of motion events. Specifically, we would expect them to process manner and path serially. Visual fixation time has often been argued to reflect processing time (e.g., Colombo, Mitchel, O'Brien, & Horowitz, 1987; Morrongiello, 1988). Thus, if infants process manner and path serially, their looking times to events in which two features have changed should be longer than their looking times to events in which a single feature has changed.

Regardless of whether infants treat manner and path as independent, we predict that they will, minimally, succeed at discriminating between the composite events. This would be evidenced by looking longer to the path change, manner change, and both change events than to the control event. As perception of change logically precedes detecting manner and path as independent features, this finding in and of itself would represent an important step on the road toward conceptualizing manner and path in motion events.

Method

Participants

Forty-six monolingual infants between the ages of 7 and 9 months (21 male; M = 7,27, range = 6,28–8,29) from English-speaking households in a small mid-Atlantic city in the United States participated. Data from an additional 36 infants (roughly 32%) were excluded for reasons potentially related to task difficulty: Sixteen infants were excluded for fatigue because they failed to meet the recovery criterion of renewed interest in a video of a laughing baby at the end of the experiment, 12 failed to reach the habituation criterion, and 8 failed to complete the experiment due to fussiness. This attrition rate did not significantly differ between genders (20 excluded for 21 usable boys vs. 16 excluded for 25 usable girls; independent samples Mann–Whitney U: p = .376). Data from 28 additional infants (roughly 25%) were excluded for reasons not related to the task: parental or sibling interference (14), computer or experimenter error (7), background noise (6), excessive movement preventing accurate coding (1), and failure to reattend to the attention-getting stimulus between trials (1). Attrition rates above 50% are not uncommon in infant experiments (Oates, 1998; Wachs & Smitherman, 1985).

Stimuli

The methodology used was identical to that of Pulverman, Golinkoff, et al. (2008). Stimuli were Pulverman, Golinkoff, et al.'s computer-animated motion events featuring a lavender starfish character performing an action, and a stationary green ball on a black background (see Figure 1). The ball served as the reference point for the starfish's paths, because path is defined as a moving entity's trajectory *with respect to a reference point* (Talmy, 1985). Each action included one of three manners (jumping jacks, spinning, or bending at the "waist") and one of three paths (over, under, or past the ball; Figure 1) resulting in nine distinct actions (jumping jacks over, jumping jacks under, etc.). The starfish traversed its path over 6 s and then reversed its direction to continue back along the same path. These back-and-forth paths were chosen so the starfish would not disappear and reappear in a different location between repetitions of the path. They were also chosen so that children had to process dynamic motion and could not rely on sources or goals to infer the paths based on static start or endpoints. The manners were all repetitive, and reversed their direction concurrently with the paths' direction changes. For example, in the "spinning over" event, the starfish took 6 s to cross from the left side of the screen to the right side, passing over the ball, while continuously spinning clockwise. In the next 6 s, the starfish passed over the ball from right to left while spinning counterclockwise. Crucially, no language accompanied the events, so results reflected event processing in general and not specifically in a word-learning context.

Procedure

Infants were seated in a dimly lit room on a parent's lap at a table in front of a computer monitor. Parents were instructed to close their eyes and refrain from speaking or directing their child's attention toward the screen during the study. Stimuli were presented via the computer program Habit 2000 (Cohen, Atkinson, & Chaput, 2000). An experimenter blind to the habituation and test stimuli being displayed observed the infants through a peephole and coded whether the infants were attending to the screen.

Fifteen percent of the participants' tests ($n = 7$) were recoded offline from videotapes by a second coder to check reliability. For all recodings, visual fixation times during trials had a Pearson correlation of at least .99 with the original, online codings.

Participants were habituated to one of the nine stimulus events (e.g., jumping jacks over). Infants were considered habituated when their visual fixation time to the stimulus in a fixed, nonoverlapping window of three consecutive trials (e.g., Trials 4–6, Trials 7–9, etc.) dropped to or below 65% of their visual fixation time in the first window (i.e., Trials 1–3). Infants who did not reach the habituation criterion within 15 trials were excluded from the sample. Once habituated, each participant was presented with four test trials: a control trial with the same event as the habituation trials (e.g., jumping jacks over); a path change trial with the same manner as the habituation event, but a different path (e.g., jumping jacks *under*); a manner change trial with the same path as the habituation event, but a different manner (e.g., *spinning* over); and a both change trial whose manner and path were both different from those in all of the other events (e.g., *bending past*). Immediately following the test phase, a highly attractive recovery stimulus (a video of a laughing baby's face) was presented to check whether participants were too fatigued to look at the display at the conclusion of the study. Participants who looked less at the recovery trial than at the control trial were excluded.

Nine stimulus sets were created to counterbalance which event was presented as the habituation event, which events were used for each type of test trial, and the order of presentation of the four types of test trials (including the control trial). Participants were each randomly assigned one of the stimulus sets. In all phases of the experiment (i.e., habituation, test, and recovery) a trial ended either when the participant looked away from the stimulus for two consecutive seconds, or when the trial had lasted 30 s, whichever came first.

Results

Means and standard deviations of the visual fixation times for each type of test trial are presented by gender and in total in Table 1.

Do 7- to 9-Month-Old Infants Notice Manner and Path in Motion Events?

To determine whether preverbal infants are able to perceive manners and paths, we compared their visual fixation to each type of changed event with their visual fixation to the control event (see Figure 2). A 4 × 2 mixed model analysis of variance (ANOVA; with Huynh-Feldt corrected degrees of freedom for failure to meet the sphericity assumption of a standard ANOVA) with the within-subjects factor of trial type (control vs. path change vs. manner change vs. both change) and the between-subjects factor of gender revealed only a significant main effect of trial type, $F(2.5, 112.2) = 6.62$, $p = .001$, $\eta_p^2 = .13$. There was no significant main effect or interaction of gender (both ps > .115); thus, gender was collapsed in the following analysis.

Table 1
Mean Visual Fixation Time (s) to Each Type of Test Trial by Gender

	Control	Path change	Manner change	Both change
Boys	6.1 (5.7)	11.4 (8.5)	13.3 (9.7)	10.1 (6.6)
Girls	5.9 (4.3)	7.9 (6.0)	8.7 (6.9)	10.7 (7.0)
All	6.0 (4.9)	9.5 (7.4)	10.8 (8.5)	10.4 (6.8)

Note. Standard deviations are in parentheses.

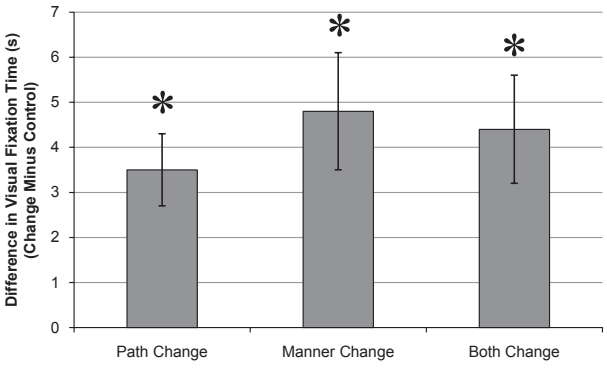

Figure 2. Mean differences in visual fixation times between each type of change trial and the control trial.
*$p < .05$.

A priori contrasts comparing each change trial directly with the control trial were used to determine which changes the infants noticed. Results showed that the infants' visual fixation times to the path change, manner change, and both change trials were each significantly longer than to the control trial: path, $F(1, 45) = 21.56$, $p < .001$, $\eta_p^2 = .32$; manner, $F(1, 45) = 12.74$, $p = .001$, $\eta_p^2 = .22$; and both, $F(1, 45) = 14.69$, $p < .001$, $\eta_p^2 = .25$. These results indicate that preverbal infants notice both manners and paths in motion events.

Do Infants Treat Manner and Path as Independent *Features of Events, or Is the Detection of Manner and Path Changes Best Characterized as Simply Noticing That the Event Is Different* as a Composite?

As adults have been shown to process multiple features serially (Lobaugh et al., 1998; Treisman & Gelade, 1980), serial processing of manner and path would suggest that manner and path are independent event features for infants. Given that every type of change has been shown to draw attention (i.e., all change trials are longer than the control), serial processing stipulates that infants should watch an event in which two features have changed longer than they watch events in which a single feature has changed. To test this hypothesis, we conducted a 2 × 2 mixed model ANOVA with the within-subjects factor of number of features that was changed (henceforth "features"; one vs. two) and the between-subjects factor of gender. In this analysis, the one-feature value for each participant was the mean duration of the manner change and path change trials, and the two-feature value was the duration of the both change trial. The main effect of features was not significant ($F < 1$); thus, we cannot conclude that 7- to 9-month-olds uniformly process manner and path as independent features. However, this finding is moderated by a significant Features × Gender interaction, $F(1, 44) = 4.48$, $p = .040$, $\eta_p^2 = .09$.

How Do Boys and Girls Differ in Their Processing of Manner and Path?

We further explored the interaction by examining the effect of features within each gender (see Figure 3). One-tailed tests were used due to the directional nature of the hypothesis (two features > one feature). The girls looked at the trials changing one feature for an average of 8.3 s ($SD = 5.4$) and the trial changing two features for an average of 10.7 s ($SD = 7.0$). A paired-samples t test confirmed that changing two features garnered more attention than changing one feature, $t(24) = 1.74$, $p = .048$, $d = .36$. The boys looked at the trials changing one feature for an average of 12.3 s ($SD = 7.0$) and the trial changing two features for an average of 10.1 s ($SD = 6.6$). A paired-samples t test revealed no significant difference between these values, $t(20) = -1.29$, $p = .107$, $d = .28$. These analyses suggest that girls process manner and path as independent features of events by 7–9 months of age, but boys may simply process the events as composites without detecting manner and path as two distinct features.

The features analyses test a rough model of serial processing—if features are processed one after another, then more features should take longer to process. A precise model of serial processing states exactly *how much longer* processing multiple features should take. Specifically, independent feature processing should be *additive*—if manner and path are processed one after another, then attention to changes in both the manner and path together should be equal to the sum of a change in just manner and a change in just path (henceforth "the sum"; see Figure 4). To assess this hypothesis, we must first isolate attention to the *changes* in the events. For this reason, the values we use in our analyses of additivity control for attention to all the familiar (i.e., habituated) features of the events by subtracting out the value of the control trial. Confirming additivity statistically is impossible, as the model predicts a null finding. However, it should be noted that the sum and attention to the both change were *identical* for the girls (sum: $M = 4.8$ s, $SD = 10.2$ s; both change: $M = 4.8$ s, $SD = 7.3$), suggesting that their manner and path processing were indeed additive. In contrast, for the boys, the sum averaged 12.4 s ($SD = 11.6$) and the both change averaged 4.0 s ($SD = 8.6$). A paired

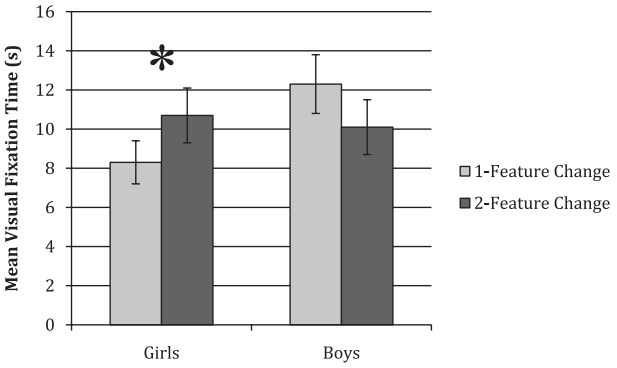

Figure 3. Effect of number of features.
*$p < .05$ (one-tailed).

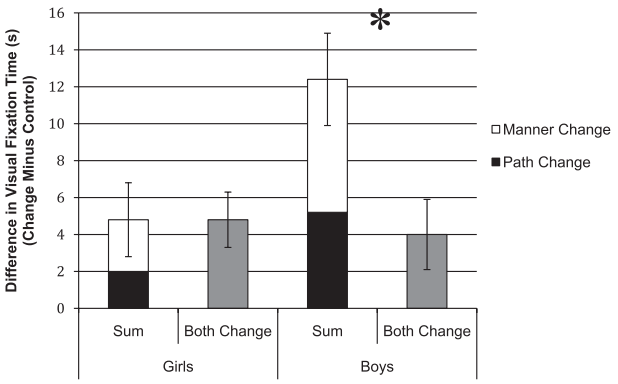

Figure 4. Additivity of manner and path.
*$p < .05$ (two-tailed).

samples, two-tailed t test indicated that these values significantly differ, $t(20) = 3.51$, $p = .002$, $d = .79$, thereby showing that the boys' attention to manner and path was not additive. Importantly, our conclusions for both genders are now supported by significant findings—a significant effect of features suggests that girls process manner and path as independent features, and a significant effect of additivity suggests that boys do not.

Lastly, we explored whether boys differed from girls in the amount of time or number of trials they took to habituate to our stimuli. Independent samples, two-tailed t tests comparing gender revealed no significant difference between boys and girls in the number of habituation trials (girls: $M = 8.4$ trials; boys: $M = 9.4$ trials), $t(44) = 1.27$, $p = .211$, $d = .38$, or in total visual fixation time across the habituation phase (girls: $M = 125.4$ s; boys: $M = 157.9$ s), $t(44) = 1.54$, $p = .131$, $d = .46$. Thus, the gender difference that emerged in the independence analyses cannot be ascribed to differences in general attention levels.

Discussion

This study investigated preverbal English-learning infants' processing of manner and path in silent motion events. This research was motivated by the fact that a fundamental prerequisite for learning verbs and other relational terms is the ability to attend to the paths and manners of events. Path and manner, along with other conceptual elements such as figure, ground, source, and goal, are features of motion events that will be relevant for learning verbs and other relational terms. Attention to path and manner were tested in a habituation paradigm using perceptually simple, animated events involving one character—a starfish—moving in various manners along various paths with respect to a reference point—a ball. The study was designed to address three questions about the development of infants' manner and path processing: (a) Do preverbal infants *notice* the manners and paths of motion events? (b) Do infants process manner and path as *independent* features of events? (c) How do boys and girls differ in their processing of manner and path?

Do Preverbal Infants Notice the Manners and Paths of Motion Events?

Our first major finding is that by 7 months of age, infants perceive differences between events if the manner and/or path has changed. The discrimination findings show that these preverbal infants can distinguish between the composite events, even if they are unaware that the event is made up of separable features. Recognizing that such events are different is a first step toward extracting exactly *what* changed in the event. Manner and path concepts can only be constructed if the features are perceived. The current research provides evidence that by 7 months of age, the rudimentary foundation for learning motion verbs and other relational terms is in place.

Do Infants Process Manner and Path as Independent Features of Events and Does This Ability Differ in Boys and Girls?

Our second major finding is that the ability to process manner and path as independent features of events develops over time, with boys lagging behind girls. Preverbal girls showed evidence of treating manner and path as independent, but boys of the same age did not. Although the current study involves a single age group, we believe our results show evidence of a developmental change. In the absence of further research, there is no compelling reason to believe that boys' and girls' event processing differ in their fundamental nature. Rather, it is more likely that event processing develops in all infants in the same way, but with boys lagging behind girls during the time period we tested. Indeed, a reanalysis of Pulverman, Golinkoff, et al.'s (2008) data using the features and additivity analyses from the current experiment reveals no significant gender interactions in English- or Spanish-learning 14- to 17-month-olds. Across both genders, number of features is significant and additivity is nonsignificant. By the first

half of the 2nd year of life, when infants are in the early stages of word learning, boys and girls alike appear to have developed the ability to process manner and path as independent event features. Thus, they have mastered a crucial prerequisite for learning a wide variety of dynamic relational terms such as verbs, prepositions, and adverbial expressions.

Why girls would be ahead of boys in developing independent representations of manner and path is not clear. The direction of this gender effect is particularly surprising given that the task probed the processing of dynamic *spatial* relations; typically, gender differences on spatial tasks and spatial language production indicate a male advantage (Levine et al., 1999; Linn & Petersen, 1985; Maccoby & Jacklin, 1974; Pruden, Levine, & Huttenlocher, 2010; Voyer et al., 1995). Recent studies have shown male advantages on mental rotation tasks in infants as young as 3–5 months of age (Quinn & Liben, 2008).

We suggest that the gender differences that emerged in the current studies were not a result of the spatial nature of the task per se; both boys' and girls' representations of the events included information about both the manner and path, as evidenced by their successful discrimination of the composite events. Rather, we propose that the gender differences may have stemmed from a process we call *conceptual semantic decomposition*—representationally breaking down an event or scene into conceptually meaningful parts. Conceptually decomposing events into semantic features including manner and path is a crucial underpinning for language. Thus, the gender differences we found may be related not to the spatial demands of our task, but rather to the linguistically relevant conceptual demands. This raises the intriguing question of whether part of the reason that young girls are more advanced than young boys on so many linguistic tasks (Bauer et al., 2002; Bornstein, Hahn, et al., 2004; Fenson et al., 1994) could be that some pieces of the cognitive foundation for language are in place earlier for girls than for boys. Alternatively, perhaps an underlying third factor drives gender differences in both conceptual semantic decomposition and language development (e.g., parental input, IQ). One possibility is that early parental input, in the form of spatial language, promotes children's attention to spatial aspects of the world. Indeed, there is recent research to suggest that parental spatial language input not only predicts children's later spatial language production but also their later nonlinguistic spatial skills (Pruden, Levine, & Huttenlocher, 2011; Pruden et al., 2010). Thus, it could be that parents influence a child's ability to perceive and make sense of the spatial world. Further research is needed to investigate these possibilities.

Convergent Evidence of Independent Manner and Path Processing

Converging evidence from work on motion event categorization by Pruden and colleagues (Pruden, Göksun, Roseberry, Hirsh-Pasek, & Golinkoff, 2012; Pruden, Roseberry, Göksun, Hirsh-Pasek, & Golinkoff, in press) supports the claim that our features and additivity analyses tap the question of independent processing. To form a category of events, infants must detect an *invariant* element across a number of events that differ. If infants process events as composites, they can only determine that the events are different; if they process the events in terms of independent features, they may also recognize that one feature is the same across the events.

Using similar events with the same animated starfish performing a superset of the manners and paths from the current studies, Pruden et al. (2012) familiarized English-learning infants to four events that all shared the same manner but had different paths. The infants were then tested on an *in-category* event with the familiar manner and a novel path versus an *out-of-category* event with a novel manner and a novel path. A reanalysis of the Pruden et al. data incorporating gender in the analysis of individual age groups shows that 7- to 9-month-old infants' ability to form a category of events based on a common manner interacted with gender. The girls exhibited evidence of successfully categorizing the events, but the boys did not.

Pruden et al.'s (2012) experiment serves as strong evidence that 7- to 9-month-old girls process manner and path as independent features of events. Girls were able to categorize distinct events based on their manners, a result that would not have been possible if they had processed the events as composites. In contrast, the boys did not show reliable evidence of categorization. This is exactly what the results of the current experiments would predict; the differentiation between one- and two-feature changes and the additivity of attention to manner and path appear to reflect the detection of manner and path as separable event features.

Taken together, the current findings, in conjunction with the reanalysis of Pruden et al. (2012), suggest that infants are not endowed with the concepts of manner and path as separable features of events

from the outset. This raises the important question of *how* manner and path concepts develop. The current studies offer a potential solution to this problem.

How Does the Basic Ability to Perceptually Discriminate Composite Events Develop Into a Conceptual Differentiation Between Manners and Paths as Features?

Recent findings in cognitive neuropsychology suggest a potential solution to this problem. Wu et al. (2008) reported that when adults made judgments about animated events in which the starfish from the current studies performed actions with manners and paths, different areas of the brain responded to manner and path information. Perception of and attention to paths activated more dorsal regions, while perception of and attention to manners activated more ventral regions. Thus, the "where" (path) and the "what" (manner) of motion event processing in adults respects the dorsal-ventral division of the "where" and "what" visual pathways that have been widely attested in object processing. Wilcox et al. (2009) provide the first evidence of separate neural correlates of "where" and "what" object processing in infants. They report temporal cortex activation (a part of the ventral "what" pathway in adults) when 6½-month-olds observed a featural change in an object, but not when they viewed a spatiotemporal discontinuity in the object's movement. In addition, Wilcox et al. reported less robust activation of the temporal cortex as compared to the visual cortex, and speculated that this difference reflects greater immaturity in the temporal region. Taken together, these studies suggest that infants' event processing may develop in conjunction with the maturation of cortical regions involved in the "where" and "what" pathways. Perceptual discrimination of composite events may be accomplished early by the more mature visual cortex, while independent path and manner processing may emerge later as other regions with dorsal-ventral "where–what" divisions develop. Further functional neuroimaging research to complement infant behavioral studies will be invaluable in advancing our understanding of the development of event processing.

Conclusions

From these experiments, a picture of the cognitive foundation for verb and other relational term learning begins to emerge. Even before infants begin to readily learn words, the rudimentary base upon which the motion verb and relational term lexicon will be built appears to be in place, though not in its full complexity. By 7–9 months of age, infants discriminate between events with differing manners or differing paths, and are beginning to develop the ability to process manner and path independently. Thus, these concepts appear to develop early and be in place by the time infants dive into word learning around the beginning of their 2nd year. This supports theoretical arguments that the widely attested difficulty young children have learning verbs in many languages reflects a problem mapping verbs onto their corresponding concepts (Gentner, 1982; Gillette et al., 1999). The concepts themselves appear to be readily available to support the learning of verbs and other dynamic relational terms.

References

Bauer, D. J., Goldfield, B. A., & Reznick, S. J. (2002). Alternative approaches to analyzing individual differences in the rate of early vocabulary development. *Applied Psycholinguistics*, *23*, 313–336. doi:10.1017/S0142716402003016

Bornstein, M., Cote, L., Maital, S., Painter, K., Park, S. Y., Pascual, L., et al. (2004). Cross-linguistic analysis of vocabulary in young children: Spanish, Dutch, French, Hebrew, Italian, Korean and American English. *Child Development*, *75*, 1115–1140. doi:10.1111/j.1467-8624.2004.00729.x

Bornstein, M. H., Hahn, C. S., & Haynes, O. M. (2004). Specific and general language performance across early childhood: Stability and gender considerations. *First Language*, *24*, 267–304. doi:10.1177/0142723704045681

Bornstein, M. H., Mash, C., & Arterberry, M. E. (2011). Perception of object-context relations: Eye-movement analyses in infants and adults. *Developmental Psychology*, *47*, 364–375. doi:10.1037/a0021059

Casasola, M. (2008). The development of infants' spatial categories. *Current Directions in Psychological Science*, *17*, 21–25. doi:10.1111/j.1467-8721.2008.00541.x

Casasola, M., Bhagwat, J., & Ferguson, K. T. (2006). Precursors to verb learning: Infants' understanding of motion events. In K. Hirsh-Pasek & R. M. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 160–190). New York: Oxford University Press.

Casasola, M., & Cohen, L. B. (2002). Infant categorization of containment, support and tight-fit spatial relationships. *Developmental Science*, *5*, 247–264. doi:10.1111/1467-7687.00226

Casasola, M., Hohenstein, J., & Naigles, L. R. (2003, April). Ten-month-old infants' discrimination of manner and path in motion events. In M. Casasola (Chair),

From infancy to adulthood: Exploring the effect of linguistic input on the discrimination of manner and path in motion events. Symposium conducted at biennial meeting of the Society for Research in Child Development, Tampa, FL.

Caselli, M. C., Bates, E., Casadio, P., & Fenson, J. (1995). A cross-linguistic study of early lexical development. *Cognitive Development*, *10*, 159–199. doi:10.1016/0885-2014(95)90008-X

Choi, S. (1998). Verbs in early lexical and syntactic development in Korean. *Linguistics*, *36*, 755–780. doi:10.1515/ling.1998.36.4.755

Choi, S. (2006). Preverbal spatial cognition and language-specific input: Categories of containment and support. In K. Hirsh-Pasek & R. M. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 191–207). New York: Oxford University Press.

Choi, S., & Bowerman, M. (1991). Learning to express motion events in English and Korean: The influence of language-specific lexicalization patterns. *Cognition*, *42*, 83–121. doi:10.1016/0010-0277(91)90033-Z

Choi, S., & Gopnik, A. (1995). Early acquisition of verbs in Korean: A cross-linguistic study. *Journal of Child Language*, *22*, 497–529. doi:10.1017/S0305000900009934

Choi, S., McDonough, L., Bowerman, M., & Mandler, J. M. (1999). Early sensitivity to language-specific spatial categories in English and Korean. *Cognitive Development*, *14*, 241–268. doi:10.1016/S0885-2014(99)00004-0

Cohen, L. B., Atkinson, D. J., & Chaput, H. H. (2000). Habit 2000: A new program for testing infant perception and cognition (Version 2.2.5c) [Computer software]. Austin: University of Texas.

Colombo, J., Mitchel, D. W., O'Brien, M., & Horowitz, F. (1987). Stability of visual habituation during the first year of life. *Child Development*, *58*, 474–487.

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 (Ed.), *Language development: Vol. 2. Language, thought, and culture* (pp. 301–334). Hillsdale, NJ: Erlbaum.

Gillette, J., Gleitman, H., Gleitman, L., & Lederer, A. (1999). Human simulations of vocabulary learning. *Cognition*, *73*, 135–176. doi:10.1016/S0010-0277(99)00036-0

Göksun, T., Hirsh-Pasek, K., & Golinkoff, R. M. (2009). Processing figures and grounds in dynamic and static events. *Proceedings of the Annual Boston University Conference on Language Development*, *33*, 199–210.

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. doi:10.1016/j.cognition.2011.07.002

Hespos, S. J., & Spelke, E. S. (2004). Conceptual precursors to language. *Nature*, *430*, 453–456. doi:10.1038/nature02634

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. *Developmental Psychology*, *27*, 236–248. doi:10.1037/0012-1649.27.2.236

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. doi:10.1111/j.1467-8624.2008.01171.x

Jackendoff, R. (1983). *Semantics and cognition*. Cambridge, MA: MIT Press

Kersten, A. W. (1998). A division of labor between nouns and verbs in the representation of motion. *Journal of Experimental Psychology*, *127*, 34–54. doi:10.1037/0096-3445.127.1.34

Kersten, A. W., & Billman, D. (1997). Event category learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *23*, 638–658. doi:10.1037/0278-7393.23.3.638

Kersten, A. W., Meissner, C. A., Lechuga, J., Schwartz, B. L., Albrechtsen, J. S., & Iglesias, A. (2010). English speakers attend more strongly than Spanish speakers to manner of motion when classifying novel objects and events. *Journal of Experimental Psychology: General*, *139*, 638–653. doi:10.1037/a0020507

Lakusta, L., & Landau, B. (2005). Starting at the end: The importance of goals in spatial language. *Cognition*, *96*, 1–33. doi:10.1016/j.cognition.2004.03.009

Lakusta, L., Wagner, L., O'Hearn, K., & Landau, B. (2007). Conceptual foundations of spatial language: Evidence for a goal bias in infants. *Language Learning and Development*, *3*, 179–197. doi:10.1080/15475440701360168

Langacker, R. W. (1987). Nouns and verbs. *Language*, *63*, 53–94.

Levine, S. C., Huttenlocher, J., Taylor, A., & Langrock, A. (1999). Early sex differences in spatial skill. *Developmental Psychology*, *35*, 940–949. doi:10.1037/0012-1649.35.4.940

Linn, M. C., & Petersen, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development*, *56*, 1479–1498. doi:10.2307/1130467

Lobaugh, N. J., Cole, S., & Rovet, J. F. (1998). Visual search for features and conjunctions in development. *Canadian Journal of Experimental Psychology*, *52*, 201–212. doi:10.1037/h0087293

Ma, W. (2009). *How does meaning specificity affect adults' and children's verb learning and extension?* Unpublished dissertation, University of Delaware, Newark.

Ma, W., Golinkoff, R. M., Hirsh-Pasek, K., McDonough, C., & Tardif, T. (2009). Imageability predicts the age of acquisition of verbs in Chinese children. *Journal of Child Language*, *36*, 405–423. doi:10.1017/S0305000908009008

Maccoby, E. E., & Jacklin, C. N. (1974). *The psychology of sex differences*. Stanford, CA: Stanford University Press.

Mandler, J. M. (1992). How to build a baby: II. Conceptual primitives. *Psychological Review*, *99*, 587–604. doi:10.1037/0033-295X.99.4.587

Mandler, J. M. (1996). Preverbal representation and language. In P. Bloom, M. A. Peterson, L. Nadel, &

M. F. Garrett (Eds.), *Language and space* (pp. 365–384). Cambridge, MA: MIT Press.

Mandler, J. M. (2004). *Foundations of mind: Origins of conceptual thought*. New York: Oxford University Press.

McDonough, L., Choi, S., & Mandler, J. M. (2003). Understanding spatial relations: Flexible infants, lexical adults. *Cognitive Psychology*, *46*, 229–259. doi:10.1016/S0010-0285(02)00514-5

Morrongiello, B. (1988). Habituation, fixation, and cognitive activity: Another "look" at the evidence. *European Bulletin of Cognitive Psychology*, *8*, 489–493.

Naigles, L. R., Hoff, E., & Vear, D. (2009). Flexibility in early verb use: Evidence from a multiple-N diary study. *Monographs of the Society for Research in Child Development*, *74*(2, Serial No. 293).

Nelson, K. (1989). *Narratives from the crib*. Cambridge, MA: Harvard University Press.

Oates, J. (1998). Risk factors for infant attrition and low engagement in experiments and free-play. *Infant Behavior and Development*, *21*, 555–569. doi:10.1016/S0163-6383(98)90029-7

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. doi:10.1111/j.1467-8624.2012.01737.x

Pruden, S. M., & Levine, S. C. (2011, April). *Factors affecting spatial language development: Are there sex differences?*, Poster presented at the biennial meeting for the Society for Research in Child Development, Montreal, Canada.

Pruden, S. M., Levine, S. C., & Huttenlocher, J. (2010, March). Individual differences in children's spatial language use predicts later spatial cognition. In S. Roseberry & T. Göksun (Chairs), *When representational systems collide: Aligning space and language.* Symposium conducted at the International Conference on Infant Studies, Baltimore, MD.

Pruden, S. M., Levine, S., & Huttenlocher, J. (2011). Children's spatial thinking: Does talk about the spatial world matter? *Developmental Science*, *14*, 1417–1430. doi:10.1111/j.1467-7687.2011.01088.x

Pruden, S. M., Roseberry, S., Göksun, T., Hirsh-Pasek, K., & Golinkoff, R. M. (in press). Infant categorization of path relations during dynamic events. *Child Development*.

Pulverman, R., Golinkoff, R. M., Hirsh-Pasek, K., & Sootsman Buresh, J. (2008). Infants discriminate manners and paths in non-linguistic dynamic events. *Cogntion*, *108*, 825–830. doi:10.1016/j.cognition.2008.04.009

Pulverman, R., Hirsh-Pasek, K., Golinkoff, R. M., Pruden, S., & Salkind, S. J. (2006). Conceptual foundations for verb learning: Celebrating the event. In K. Hirsh-Pasek & R. M. Golinkoff (Eds.), *Action meets word: How children learn verbs* (pp. 134–159). New York: Oxford University Press.

Pulverman, R., Rohrbeck, K., Chen, P., & Ulrich, A. (2008, November). *Specificity of meaning predicts verb acquisition in English and Mandarin Chinese.* Paper presented at the 33rd Annual Boston University Conference on Language Development, Boston, MA.

Pulverman, R., Tardif, T., Rohrbeck, K. L., & Chen, P. (2010, March). *The effect of specificity on verb acquisition: Evidence from English and Mandarin Chinese*. Poster session presented at the 17th Biennial International Conference on Infant Studies, Baltimore, MD.

Quinn, P. C., & Liben, L. S. (2008). A sex difference in mental rotation in young infants. *Psychological Science*, *19*, 1067–1070. doi:10.1111/j.1467-9280.2008.02201.x

Shipley, T. F., & Zacks, J. M. (Eds.) (2008). *Understanding events: From perception to action*. New York: Oxford University Press.

Slobin, D. I. (2004). The many ways to search for a frog: Linguistic typology and the expression of motion events. In S. Strömqvist & L. Verhoeven (Eds.), *Relating events in narrative: Vol. 2. Typological and contextual perspectives* (pp. 219–257). Mahwah, NJ: Erlbaum.

Talmy, L. (1985). Lexicalization patterns: Semantic structure in lexical forms. In T. Shopen (Ed.), *Language typology and the lexicon: Vol. 3: Grammatical categories and the lexicon* (pp. 57–149). Cambridge, England: Cambridge University Press.

Tardif, T. (1996). Nouns are not always learned before verbs: Evidence from Mandarin speakers' early vocabularies. *Developmental Psychology*, *32*, 492–504. doi:10.1037/0012-1649.32.3.492

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*, 97–136.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*, *117*, 250–270. doi:10.1037/0033-2909.117.2.250

Wachs, T. D., & Smitherman, C. H. (1985). Infant temperament and subject loss in a habituation procedure. *Child Development*, *56*, 861–867. doi:10.2307/1130098

Wagner, L., & Carey, S. (2005). Twelve-month-old infants represent probable endings of motion events. *Infancy*, *7*, 73–83. doi:10.1207/s15327078in0701_6

Wilcox, T., Bortfeld, H., Woods, R., Wruck, E., Armstrong, J., & Boas, D. (2009). Hemodynamic changes in the infant cortex during the processing of featural and spatiotemporal information. *Neuropsychologia*, *47*, 657–662. doi:10.1016/j.neuropsychologia.2008.11.014

Wu, D. H., Morganti, A., & Chatterjee, A. (2008). Neural substrates of processing path and manner information of a moving event. *Neuropsychologia*, *46*, 704–713. doi:10.1016/j.neuropsychologia.2007.09.016

Wynn, K. (1992). Children's acquisition of the number words and the counting system. *Cognitive Psychology*, *24*, 220–251.