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Current Events: How Infants Parse the World and Events for Language

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To appear in T. F. Shipley & J.M. Zacks (Eds.), *Understanding events: How humans see, represent, and act on events*. New York, NY: Oxford University Press. This work was supported by NSF Grants SBR9601306 and SBR9615391 to the second and third authors and NICHD Grant 3U10HD25455-0552 to the second author.

Current events: How infants parse the world and events for language

At the critical juncture between words and grammar, lies the next frontier -- verb learning. Serving as the architectural centerpiece of the sentence, verbs control the argument structure of grammar and describe relations between objects and events. Verbs are windows onto language capturing descriptions of events. Though verbs appear in the vocabulary of very young children (Choi, 1998; Choi & Bowerman, 1991; Choi & Gopnik, 1995; Fenson, Dale, Reznick, & Bates, 1994; Nelson, 1989; Tardif, 1996), noun acquisition has dominated the focus in the field of language development. Fundamental to developing a comprehensive theory of word learning is the study of early verb learning; fundamental to the study of verbs is the study of how young children perceive, process, and represent events. This chapter focuses on what children need to know about events before they learn their first verbs and more broadly, their first relational terms. What are the conceptual foundations of verb learning? How do children process actions and events?

Research within the last two decades has begun to illuminate the process through which children acquire a lexicon of relational terms (see Hirsh-Pasek & Golinkoff, 2006 for a review of this research). This research shows that verbs are more difficult to learn than nouns (Gentner, 1982; also see Bornstein et al., 2004; but see Tardif, 1996 for counterarguments). For example, Meyer et al. (2003), and Imai, Haryu, and Hiroyuki (2003) find that well into the 5th year, children have trouble determining the referent of a novel verb in both English and Japanese. Even in languages like Korean, where verbs are in perceptually favored, sentence-final positions and can appear alone in a sentence, children tend to learn verbs later than nouns (e.g., Choi & Bowerman, 1991; Choi & Gopnik, 1995; but see Tardif, 1996 for an alternative view). Further, research with adult populations, like Gillette and colleagues' (1999) "Human Simulation Project"

suggests that conceptually mature adults find it hard to clearly demarcate the meaning for a verb. Asked to view silent videos of interactions between English-speaking mothers and their children, adults are fairly good at guessing which nouns the mother is likely saying (e.g., 45% correct). In contrast, when asked to guess the verbs the mother is likely saying, adults do much more poorly (e.g., 15% correct). What makes verbs and other relational terms so difficult to learn?

It has been suggested that learning verbs requires some key abilities. For example, Gentner and Boroditsky (2001) outline two critical prerequisites for acquiring verbs. According to these researchers, verb learning requires: (1) the conceptualization of actions and relations, and (2) the mapping of words to these actions and relations. Golinkoff and colleagues (2002) echoed Gentner and Boroditsky suggesting that infants must pay attention to and isolate actions and relations within a larger event before they can then form categories of these actions/relations and map words on to these actions/relations. Thus, the conceptualization of actions and events might be part of the verb-learning problem. Further, verbs do not label whole actions but only a subset of actions or what has been termed, "semantic components." These semantic components include meaning elements like, *path* (i.e., or the trajectory of the object or agent; e.g., come, approach, enter), *manner* (i.e., or the way in which an agent moves; e.g., walk, dance, swagger, sway, stroll), *motion* (i.e., the general fact that motion is taking place), *figure* (i.e., the primary agent or object in the event), *ground* (i.e., the reference point for the event's path), and *cause* (i.e., the cause of the figure's motion; Talmy, 1985).

In what has been dubbed the "packaging problem" (Tomasello, 1995), these semantic components are combined or configured in different ways to generate the verb system in a particular language (Talmy, 1985; also see Langacker, 1987). For example, languages like English, German, and Chinese package the *manner* of motion in verbs, while other languages,

including Spanish, Turkish, and Greek encode manner information in other word classes. Languages like English tend to reserve information about the *path* for other word classes (e.g., prepositions such as "over"), while Spanish, Turkish, and Greek, encode path information in their verbs. Infants must learn which semantic components are being encoded in a particular relational term or verb. As a result, infants may require much experience with their native language before they can recognize which semantic components are conflated in which relational terms and before they can map these semantic components themselves onto relational terms

Most research investigating relational terms has explored either the early production of relational terms such as prepositions (Choi & Bowerman, 1991; Choi & Gopnik, 1995; Tardif, 1996) or the mapping of relational terms onto actions (Choi, McDonough, Bowerman, & Mandler, 1999; Maguire, Hirsh-Pasek, Golinkoff, & Pruden, 2003; Naigles, 1996). Little research, however, investigates whether children have the necessary prerequisites to build an arsenal of relational terms. Can infants, for example, perceive events that will map to relational terms? Here we have mostly speculation. An example comes from Gentner (1982; also see Gentner & Boroditsky, 2001) who hypothesizes that the prerequisites for the learning of verbs and other relational terms might be in place at an early age. She writes,

> …relations that act as predicates over objects are, I suspect, perceived quite early. Movement, change, directionality, and so on, seem quite interesting to infants…it is not perceiving relations but packaging and lexicalizing them that is difficult. (Gentner, 1982, p. 326)

Snedeker and Gleitman agree (2004), "…vocabulary acquisition in the real case may reduce mainly to a mapping problem…" (p. 280). Further, they assert, "the young child's conceptual repertoire may be rich and varied enough from the start…" (p. 261).

Psychologists are not the only ones to propose that children start with a rich conceptual base for learning relational terms. Some cognitive linguists suggest that the semantic components that relational terms label (i.e., path, manner, etc.) may be pre-linguistic primitives from which all other relational terms are constructed (e.g., Jackendoff, 1983; Mandler, 1991; 1992; 2004), equipping infants with a language-ready organizational system. Mandler (2004) proposes that infants construct what are called "image schemas" or "spatial representation[s] that express primitive or fundamental meanings…Common image schemas are notions such as PATH, CONTAINMENT, UP-DOWN, and LINK" (p. 78). Furthermore, image schemas form the basis for conceptual categories like animacy, causality, and agency. Children conceptualize the environment around them using these image-schemas. Only after experience with their native language do infants begin to carve up these concepts into spatial categories that are particular to their native language (Hespos & Spelke, 2004).

The challenge for researchers interested in solving the verb-learning problem is to better understand the nature of events and to determine when infants understand enough about events to support the learning of relational terms. Research is just starting to focus on these issues and our laboratories have been taking this charge seriously. In the coming sections we explore infants' ability to attend to and parse actions from ongoing events. Further, we discuss infants' ability to discriminate and categorize those semantic components and relations that are codified in relational terms. Finally, we review those factors that may hinder or aid the abstraction of the semantic components encoded in relational terms.

When Do Infants Begin to Perceive, Process, and Represent Actions and Spatial Relations?

One of the hurdles for those who want to investigate the acquisition of relational terms is that little is known about how young children process events, actions, and even spatial relations.

There has been minimal research on this topic as there is still disagreement among researchers regarding the definition of an *event* (see Shipley, this volume). Some define events broadly as "what happens to things" (Kable, Lease-Spellmeyer, & Chatterjee, 2002, p. 795) or as a "basic unit in the organization of experience, memory, and meaning" (Avrahami & Kareev, 1994, p. 239). Others are more specific in their criteria for an event. Miller and Johnson-Laird (1976) for example, hold that an event must have at least two actors and include a causal relationship. In this chapter, we adopt Zacks and Tversky's (2001) definition of an event: an event is "a segment of time at a given location that is conceived by an observer to have a beginning and an end" (p. 3). Note that these beginnings and ends are not always easy to detect. As Hanson and Hirst (1989) write,

> These boundaries may be fuzzy; the exact moment of transition between one event and the next may not be clear. As one reaches for a piece of toast and picks it up, the transition between *reaching* and *picking up* may be smooth, but the lack of a precise boundary does not imply that *reaching* and *picking up* are not discrete events. Events, like object categories, can have fuzzy boundaries and yet still be distinguished from one another. (p. 136)

As indicated above, events (such as picking up the toast) can be nested in other events (such as eating breakfast) and can be divided into smaller events or into actions units (Hanson & Hirst, 1989). As another example, consider the event of *putting gas in a car.* It can be divided into smaller units such as *purchasing the gas, opening the gas tank, lifting the gas pump hose*, and *pressing the gas pump lever*. Indeed, even the event *purchasing the gas* can be divided into *getting out a wallet, giving money to a cashier*, and so forth. Before infants map words onto these events, they must have a basic understanding of how to process events and actions in their

environment (Nelson, 1997). That is, they must understand that the events *giving money to a cashier* and *taking money from the cashier* are different before they can attach the corresponding labels, *give* and *take*. Furthermore, infants need to grasp the relation between the giver and recipient of the objects they exchange.

Research investigating infants' perception of motion in events has generally looked at how infants use motion to track objects and learn about the properties of objects (see Johnson, Amso, Frank, & Shuwairi, this volume for a discussion of object perception; also see, Johnson & Aslin, 1995; Johnson, Cohen, Marks, & Johnson, 2003; Kellman & Spelke, 1983; Rakison, 2003; Rakison & Poulin-Dubois, 2001; Rochat & Hespos, 1996; Slater, Morison, & Town, 1985; Smith, Johnson, & Spelke, 2003; Spelke, Phillips, & Woodward, 1995; Wang, Kaufman, & Baillargeon, 2003). The work concentrating on infants' understanding of motion itself has focused on how infants construe the physical properties of actions within an event or the "physics" of causal events.

Some have charted infants' ability to discriminate actions and spatial relations within larger events. Five-month-olds, for example, detect the invariant property of rigid motion and can differentiate between rigid movement and deformations (Gibson, Owsley, & Johnston, 1978). In this study, infants were habituated to three types of rigid motion (e.g., rotation in the frontal plane, rotation around the vertical axis, rotation around the horizontal axis). They were then shown a new example of rigid motion (e.g., looming) and an example of deformation of the object during the test phase. Infants increased their attention to the deformation, but not to the new example of rigid motion suggesting that they perceive rigidity as an invariant property of an object.

In more recent research, 5.5-month-old infants were familiarized with a repetitive activity performed by a female actor (e.g., either blowing bubbles, brushing hair, or brushing teeth; Bahrick, Gogate, & Ruiz, 2002). During test, infants were simultaneously presented with a familiar action and novel action. They showed a significant preference for the novel action, suggesting that they could discriminate among these actions.

Casasola and Cohen (2000) demonstrate that 14-month-olds discriminate between the actions of *pushing* and *pulling*. Infants habituated to a pushing event (e.g., a toy car pushes a can across the screen) were shown two events at test: The same pushing event and an event depicting pulling (e.g., the toy car pulls a can across the screen). Infants reliably increased their looking times to the unfamiliar test event relative to the familiar test event. Thus, 14-month-old infants can discriminate between pushing and pulling actions, providing further support for infants' ability to discriminate actions within larger events. Similarly, research by Sharon and Wynn (1998; Wynn, 1996) examined infants' ability to discriminate between two actions. Six-month-old infants familiarized with a puppet performing the action of *jumping* were shown two test trials, the puppet *jumping* and the puppet *falling*. Infants increased attention to the new action – falling indicating that they could distinguish between actions like falling and jumping. The ability to discriminate among different actions is important for verb learning (Kersten & Billman, 1997). Though this research suggests that infants are equipped with the ability to notice motion and discriminate actions, it tells us little about the sorts of cues infants are using to carve up these events.

What cues are used to carve up events?

Adults appear to use a number of cues, including perceptual or sensory information (i.e., "bottom-up information") and information about the goal or intention of the actor (i.e., "top-

down information") to segment events into meaningful units (Zacks, 2004). For example, adults use movement features to determine where one action ends and another begins (Newtson, 1973; Newtson, Engquist, & Bois, 1977). Adults are also sensitive to information about the goals and intentions of an actor (Graziano, Moore, & Collins, 1988; Hanson & Hirst, 1989; Markus, Smith, & Moreland, 1985; Newtson, 1973). Zacks (2004) found that adults used movement features or perceptual information to identify event segments. However, he noted that information about an actor's intention or goal modulated the processing of these movement features. Taken together, these studies suggest that both types of information -- perceptual processing and intentional structure -- are used to represent and segment events. What kinds of information do infants use to carve up an ongoing stream of events?

Research by Baldwin, Baird, Saylor, and Clark (2001) begins to address this issue. Baldwin and colleagues investigated infants' ability to parse continuous, everyday events. Ten- and eleven-month-old infants were familiarized to continuously flowing action sequences (e.g., a women notices a towel on the floor, reaches for and grasps it, then moves toward a towel rack and places it on the rack). The test phase involved showing infants two different versions of the original action sequence, each containing a still-frame pause inserted at particular points in the course of the action sequence. One still-frame occurred just as the actor in the action sequence completed their intended act. The other still-frame occurred in the midst of the ongoing intentional action sequence. Infants looked longer at the test trial that interrupted the intended act than at the test trial that did not. These results suggest that infants as young as 10 months are able to parse continuously flowing behavior.

Baldwin and colleagues (2001) propose that infants' success in segmenting events could be attributed to both a high-level mechanism and a low-level mechanism, just as Zacks (2004)

found with adults. Infants could be using high-level information about an agent's intention to parse events (as in 'she wants to hang up the towel'). Alternatively, children might use low-level perceptual features of the events, such as the rapid changes in the direction of motion, to parse these events. Maguire, Shipley, Brumberg, and Ennis (2005) refer to these rapid changes in event direction as "curvature extrema" and note that adults are sensitive to them. Preliminary work from our lab suggests that between 7 and 9 months, babies are sensitive to "curvature extrema" as well (Song, Seston, Ma, Golinkoff, Shipley, & Hirsh-Pasek, 2007). Research using point-light displays adds credence to this latter explanation. Five-month-olds are sensitive to breaks in biological motion indicating that they may be using low-level markers to segment events (Bertenthal, Proffitt, & Cutting, 1984). While the debate over the kind of information infants use to succeed in parsing streams of biological motion remains, these findings provide the first evidence of infants' ability to parse individual actions from the dynamic flow of events.

One more piece of evidence on early event processing shows that infants can discriminate among causal and non-causal launching events (Cohen & Amsel, 1998; Cohen & Oakes, 1993; Leslie, 1984; Leslie & Keeble, 1987; Oakes, 1994; Oakes & Cohen, 1990). By 6 months of age, infants respond to the physical changes occurring in causal events, but cannot yet organize these events based on causality (Leslie, 1984). That is, infants at this age show evidence of the ability to encode the temporal order of events, but do not yet show the ability to assign causal roles to objects (i.e. one object is assigned an active, causal role and the other a passive role). By 10 months of age, infants begin to process causal launching events in terms of the relationship between the objects in the event and they organize these events based on causality (Cohen & Oakes, 1993). At this age, infants now show the ability to assign causal roles to individual objects – one specific object caused the other to move.

Taken together, research on infants' processing of events demonstrates clear evidence that in the first year of life children perceive actions and events, and carve up larger events into individual actions and relations (Baldwin, et al., 2001; Bertenthal et al., 1984; Casasola & Cohen, 2000; Sharon & Wynn, 1998; Wynn, 1996). Yet, these skills only take them so far. As Clark writes (2003), infants also need "to know how to decompose scenes into the constituent parts relevant to linguistic expressions in the language" (p. 168). That is, infants must also pay attention to and discriminate those components that are eventually encoded in language. Further, in order to process events for language, infants need the ability to see objects in relation to one another. What kinds of relations are codified in the world's languages? To answer this question, researchers turned to linguists who have specified a set of semantic components present across languages (Talmy, 1985). A thorough examination of these semantic components will not only give us a sense of what might be universal across languages, but may also allow us to see how these components are "packaged" in different ways across the languages of the world. Four celebrated semantic components in the literature are *containment* and *support*, and *path* and *manner*.

Discrimination of Actions and Spatial Relations

Can infants discriminate semantic components that are codified in relational terms? To better address this question, we break the research into two sections. In the first section, we discuss the research on infants' ability to discriminate the semantic components, *containment*, *support*, and *degree of fit*. Research on semantic components that are lexicalized in relational terms has primarily focused on these relations. The second section explores the research on infants' discrimination of *path* and *manner*. Until recently, less was known about infants' discrimination of these two semantic components in events.

Discrimination of containment, support, and degree of fit

The semantic component *containment*, lexicalized by the English word "in," "is conceived of as something in any fully or partially enclosed space – that is, bounded space with an inside and an outside…" (Mandler, 2004, p. 78). The semantic component, *support*, lexicalized in English by the word "on", occurs "when the Figure is in contact with – typically supported by, attached to, or encircling – an external surface of the Ground" (Choi, et al., 1999, p. 247). Finally, the semantic construct, *degree of fit*, makes a systematic distinction between interlocking surfaces (i.e., tight-fit containment and support) and those with non-interlocking surfaces (i.e., loose-fitting containment and support; Bowerman & Choi, 2001).

In the context of the infant studies presented here, these spatial relations are actually presented as dynamic relational constructs that unfold across time where the relation is marked by the endpoint of the event. That is, a hand places an object in another object. Here, the endpoint denotes the relation, containment. However, as Pulverman and colleagues (2007) point out, "the crucial distinctions between the containment/support/tight-fit relations can also be derived by examining the static endpoints of the events. That is, whether something fits tightly or loosely into a container requires only perceptual examination of the boundaries around the object. Thus, it is unclear whether infants' processing of these events is based on the *dynamic* properties of motion per se" (p. 6). That is, children may be solving these tasks using static properties rather than dynamic features of the event. Regardless of how children solve the task in these studies, these semantic components are important for further investigation as they appear to be packaged in different ways across language. For example, Korean speakers make a distinction between the degree of fit (i.e., tight-fit vs. loose-fit) regardless of containment (e.g., fitting a peg tightly into a hole) or support (e.g., fitting one Lego® tightly onto another). English-speakers, on

the other hand, make a distinction between containment and support relations, regardless of the degree of fit.

Findings on the spatial relations containment and support shows that young infants have an early understanding of these relations, (Baillargeon, 2001; 2002; Baillargeon & Wang, 2002; Hespos & Baillargeon, 2001a; 2001b) and can discriminate instances of these types of spatial relations (Hespos & Spelke, 2004).

Baillargeon and colleagues investigated young infants' rudimentary knowledge of containment and support relations (e.g., Baillargeon, 2001; 2002; Baillargeon & Wang, 2002; Hespos & Baillargeon, 2001a; 2001b) lexicalized in English as "in" and "on." In one study, 2.5-month-old, English-learning infants were shown two types events: a possible event and an impossible event (Hespos & Baillargeon, 2001a). In the possible event, infants viewed a scene in which an object was lowered into an open container. This event depicted a possible containment relation. In the impossible event, infants saw the same object lowered into a closed container. This event depicted an impossible containment relation. Infants looked longer at the impossible event indicating that they have some understanding of what happens in both a containment relation (i.e., when something is lowered into an open container it is a containment relation) and a support relation (i.e., when something is lowered onto a closed container it is a support relation). Infants not only discriminate between these two types of spatial relations, but they have an understanding of what happens in each type of spatial relation.

Hespos and Spelke (2004) asked whether 5-month-olds English-learning infants could discriminate spatial relations found in Korean, but not lexicalized in English (i.e., degree of fit -- tight-fit vs. loose-fit). Infants were habituated to an event in which an object either fit tightly or fit loosely in a container. During the test phase, infants viewed both the familiar relation and a

novel relation. For example, infants habituated to the spatial relation tight- fit were shown this familiar relation (i.e., tight-fit) and a novel relation (i.e., loose-fit) at test. Infants exhibited an increase in looking to the novel relation during test. Thus, they demonstrated an ability to discriminate between spatial concepts (i.e., degree of fit) that are not typically codified in their native language. These studies suggest that, at an early age, infants are predisposed to pay attention to the kinds of semantic components that may be relevant to later language learning.

Discrimination of path and manner

Path and *manner are* codified in many languages of the world (Jackendoff, 1983; Langacker, 1987; Talmy, 1985) although they are packaged in different ways. The semantic component of path may be one of the most central concepts for learning relational terms. Mandler (2004) suggests that path is a primitive used to acquire concepts like animacy and causality. A path primacy is seen in the production of relational terms in both hearing and deaf populations (Naigles, Eisenberg & Kako, 1992; Zheng & Goldin-Meadow, 2002). Naigles and colleagues discovered that 2-year-olds produce more path expressions than manner expressions, while Zheng and Goldin-Meadow showed that path verbs were produced more often than manner verbs in both Chinese and American deaf children. Manner is equally important to study. In order for a path to be traversed, a manner is required to propel the moving figure.

A few studies have investigated infants' ability to process and discriminate components like path and manner in non-linguistic motion events (Casasola, Hohenstein, & Naigles, 2003; Pulverman & Golinkoff, 2004; Pulverman et al., 2003). For example, Pulverman and Golinkoff (2004) studied English-learning infants' ability to pay attention to changes in path and manner in non-linguistic motion events. Seven-month-old infants were habituated to an animated starfish performing both a path and a manner (e.g., a starfish spinning [MANNER] over a ball [PATH]).

Once infants were habituated to this clip, they were shown 4 test trials: a control trial (e.g., starfish spinning [MANNER] over a ball [PATH]), a manner change trial (e.g., starfish bending [MANNER] over a ball [PATH]), a path change trial (e.g., starfish spinning [MANNER] under a ball [PATH]), and a path and manner change trial (e.g., starfish flapping [MANNER] past a ball [PATH]). Infants dishabituated to these test trials, suggesting that they noticed something had changed in these events.

Casasola, Hohenstein, and Naigles (2003) demonstrated that English-learning 10-month-olds could pay attention to and discriminate both path and manner in events involving naturalistic scenes and human agents (e.g., a young child crawling [MANNER] in front of a bush [PATH] vs. a young child hopping [MANNER] in front of a bush [PATH]). Ten-month-olds were habituated to a young child demonstrating both a path (e.g., in front of a bush) and a manner (e.g., skipping). At test, infants were shown three clips demonstrating a change in path, a change in manner, a change in both path and manner, and the clip they saw during habituation (control). Infants increased their attention to changes in both path and manner. These results provide evidence that infants pay attention to non-linguistic components of action events (such as path and manner) that relational terms typically encode.

Using the same stimuli and methods as those used in Pulverman and Golinkoff (2004), Pulverman and colleagues (2003) found that English-reared 14- to 17-month-olds, like the 7- to 9-month-olds, noticed that something in these events had changed. Unlike the younger infants who do not show evidence of noting specific changes in path and manner, these older infants viewed path and manner as independent elements of events. For example, those infants with a higher vocabulary (as assessed by the MacArthur Communicative Development Inventory) were more attentive to the change in manner than their lower vocabulary counterparts. These results

suggest that infants at this age notice components of actions typically encoded in their language and that language may play some role in the ability to notice and attend to these components. More recently, Pulverman et al. (2007) explored Spanish-reared infants' discrimination of path and manner. Spanish-learning infants, like English-reared infants, show evidence of the ability to notice changes in both path and manner. However, unlike their English-reared counterparts, Spanish-learning infants with a low vocabulary attended to manner as a specific element of interest, while the high vocabulary infants did not. Taken together, these studies show that infants bring to the task of learning relational terms the ability to discriminate those components that are lexicalized in language. Additionally, they also suggest that differential focus on these semantic components can have an impact on children's lexical acquisition across language.

These studies provide us with information about infants' ability to parse dynamic events and to attend to components that are codified in motion verbs. This is only the beginning of what infants need to know to solve the verb-learning problem however. As Oakes and Rakison state, "words refer to categories of objects and events" (2003, p. 4). That is, verbs label not single actions, but categories of actions and events. Running, for example, is considered the same action whether performed by an Olympic runner or a child. After children have the ability to parse events into distinct actions, they must look for similarities across these actions and categorize them. Words would lose their utility if each instance of an action required a different name.

Categorization of Actions and Spatial Relations

The literature presented thus far paints a portrait of an infant capable of attending to motion, parsing events, and discriminating those semantic components that are encoded in our lexicon of relational terms. However, once children learn how to parse events into distinct

actions they also must learn how to categorize these actions into meaningful units. For objects, infants must learn that both perceptually similar and dissimilar objects can be in the same category (e.g., "vehicles" includes perceptually dissimilar airplanes and cars). Likewise, in the categorization of actions and spatial relations, infants have to learn that both perceptually similar and dissimilar actions and relations can be categorized together. For example, *Dad giving a ring to Mom* and *Brother giving a soda to Sister* are categorized as the same action – *giving*, despite their perceptual dissimilarity. Thus, the next step in processing events for language, is acquiring the ability to form categories of the semantic components codified in language.

Categorization allows for "organized storage, efficient retrieval, and the capability of responding equivalently to an indefinitely large number of exemplars from multiple categories" (Quinn, 1994, p. 58). Forming categories reduces the demand on our limited memory storage and allows us to make inductive inferences about the world. Infants who form categories of spatial relations are capable of experiencing objects in a coherent spatial layout, rather than experiencing objects as spatially unrelated. Categorization of spatial relations appears to be a prerequisite to a host of skills, including spatial memory, locomotion, understanding geographic or travel maps, object recognition, reasoning about *dynamic* spatial events (like collision*)*, and acquiring a lexicon of spatial terms (Quinn, 2003). In the next sections, we explore infants' ability to categorize spatial relations that are lexicalized in relational terms.

Categorization of containment, support, and degree of fit

Baillargeon (e.g., Baillargeon, 2001; 2002; Baillargeon & Wang, 2002; Hespos & Baillargeon, 2001a; 2001b), and Hespos and Spelke (2004) showed that infants could discriminate among the spatial relations support, containment, and degree of fit. Can infants form nonlinguistic categories for all three of these spatial relations? By answering these questions

researchers begin to address whether infants have the conceptual foundations needed for learning spatial expressions in their native languages.

McDonough and colleagues (2003) familiarized 9-month-old infants from English-speaking homes with six different scenes depicting tight-fitting containment. Infants were shown one scene depicting the same relation seen during familiarization (i.e., containment) paired with another scene showing a novel relation (i.e., support). For example, infants who were familiarized with tight-fitting containment were shown a novel scene of tight-fitting containment paired with a scene depicting loose-fitting support during the test trials. Infants looked significantly longer at the familiar relation during the test trials. These findings suggest that 9-month-old infants can abstract a common relational element and categorize the spatial relation tight-fitting containment.

Casasola and Cohen (2002) also examined the types of spatial relations infants categorize prior to the acquisition of spatial language. In this study, objects presented to infants during the familiarization trials varied. Nine-month-olds from English-learning homes were habituated to four events, each depicting different pairs of objects in the same spatial relation (e.g., either containment: putting a cup in a dog bowl; support: putting a cup on an inverted dog bowl; or tight-fit: fitting a green peg in a yellow block). After habituation, infants were shown four test trials: (1) a control trial, during which they saw familiar objects in the familiar relation, (2) an object change trial, during which they saw novel objects in the familiar relation, (3) a relation change trial, during which they saw the familiar objects in a novel relation, and (4) an object/relation change trial, during which they saw novel objects in a novel relation. Those infants familiarized with containment events looked significantly longer at the novel versus familiar relationship regardless of the object change, indicating that they had formed a category

of containment despite the change in objects. Infants who saw either support or degree of fit events during habituation did not show an increase in attention to the novel relations during test. The results suggest that 9-month-olds are unable to form a category of either support or degree of fit when the objects used to depict the relation vary.

Perhaps the most stunning of the recent demonstrations comes from Casasola, Cohen, and Chiarello (2003) who investigated whether 6-month-old infants could categorize the spatial relation, containment. In a habituation task, infants were presented with different objects depicting a containment relation. After they habituated to the events, the experimenters presented a new example of the familiar spatial relation (i.e., containment) and an example of a novel spatial relation (i.e., support). Infants looked significantly longer at the novel spatial relation (i.e., support), indicating that they have formed a category of the spatial relation, containment. This experiment replicates and extends the results reported by Casasola and Cohen (2002), in which 9-month-olds demonstrated that they could categorize containment relations.

Results from these studies highlight three important points. First, preverbal infants can form nonlinguistic spatial categories of relations that are codified in relational terms. These findings provide further support for the hypothesis that infants have some of the prerequisite foundations of event processing that are needed to build a lexicon of relational terms. Second, and important to our later discussion of "abstract" spatial categorization infants are initially unable to form categories of support and degree of fit. If older infants show evidence of this ability, it would reveal a developmental trend in the categorization of spatial relations – one in which infants initially rely on the specifics of the event to abstract the common relation. Eventually this reliance on specific objects gives way to an abstraction of the relation across varying objects resulting in "abstract" spatial categories. If this hypothesis is confirmed it would

parallel the findings of Quinn and colleagues (Quinn, Adams, Kennedy, Shettler, & Wasnik, 2003; Quinn, Norris, Pasko, Schmader, & Mash, 1999) who found that the static category of *between* could only be understood in terms of the specific objects with which it was instantiated until 10 months of age.

Finally, Casasola and Cohen's (2002) data show that some spatial concepts are more accessible than others. English-learning preverbal infants were able to form a spatial category for containment, but not for support, even though both are lexicalized in English. Perhaps then, each spatial relation has its own developmental trajectory, with infants showing evidence of discrimination and categorization of these spatial relations at different ages. These results and those from McDonough and colleagues (2003) provide empirical evidence that infants both attend to and categorize some semantic primitives in the ways proposed by both Gentner (1982; Gentner & Boroditsky, 2001) and Mandler (1991; 1992; 2004). Thus, infants bring to the task of learning relational words the ability to discriminate and categorize those components that are lexicalized in their native language.

Categorization of path and manner

Though less is known about the semantic components, path and manner, we do have evidence that infants are capable of noticing and discriminating changes in both path and manner (Pulverman & Golinkoff, 2004; Pulverman, et al., 2003) and that infants can form categories of these semantic components.

Using tightly controlled, animated stimuli, we created two studies using dynamic events to address the following questions: (a) can infants abstract an invariant path across multiple exemplars of manner? and, (b) can infants abstract an invariant manner across multiple exemplars of path (Pruden, Hirsh-Pasek, Maguire, & Meyer, 2004)? Using the Preferential

Looking Paradigm (Hirsh-Pasek & Golinkoff, 1996), infants were familiarized to four events. Each event depicted an animated starfish performing both a single manner and single path (see Figure 1 for examples of the paths and manners). Three age groups, 7- to 9-months-olds, 10- to 12-month-olds, and 13- to 15-month-olds were tested. We started our investigation with infants as young as 7 months because this is the age at which infants show the ability to notice these two semantic components (Pulverman et al., 2004).

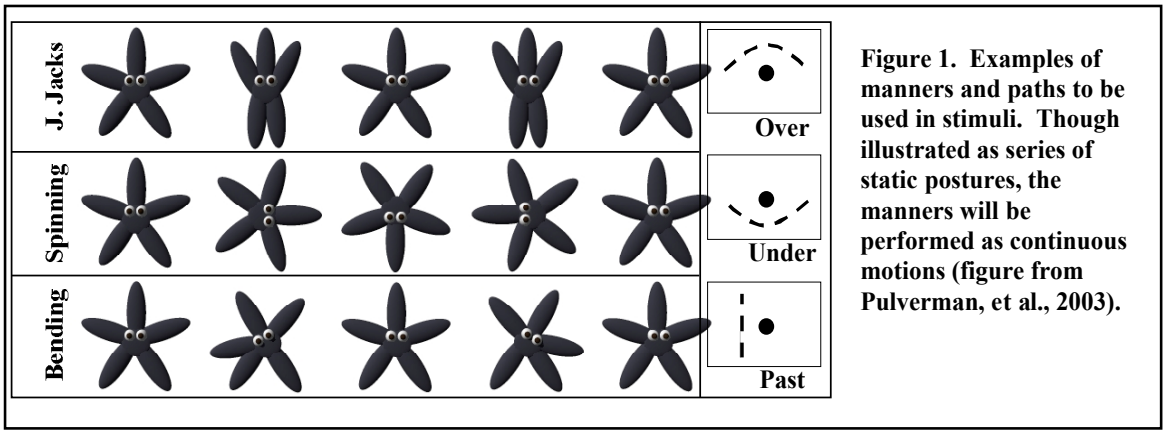

Figure 1. Examples of manners and paths to be used in stimuli. Though illustrated as series of static postures, the manners will be performed as continuous motions (figure from Pulverman, et al., 2003).

To examine whether infants could abstract an invariant path across multiple manners, infants viewed an animated starfish perform the same exact path across four distinct manners during familiarization. During the test phase, infants were shown two events simultaneously, an event depicting the same path and a novel manner, and an event depicting a novel path and novel manner. Only 10- to 12-month-old infants showed a significant preference for the familiar test event during the test phase, while infants younger than this did not show a preference at test. These findings suggest that infants as young as 10 months can abstract the invariant path across multiple exemplars of manner (Pruden et al., 2004).

We also explored infants' ability to abstract an invariant manner across multiple exemplars of path. During familiarization infants viewed four events, each depicting the same

exact manner across varying paths. At test, infants viewed both an event depicting the same manner with a novel path, and a novel manner with a novel path, simultaneously. Only the oldest age group examined, the 13- to 15-month-olds preferred to watch the novel test event. These results suggest that infants as young as 13 months can abstract an invariant manner across multiple exemplars of path. Both of these studies indicate that infants have a fundamental ability to abstract the invariant among a series of motion events.

By asking whether infants can find an invariant path or manner, we begin to explore infants' ability to form categories of these semantic components. Research will however, need to be expanded to look at when infants can move beyond simply abstracting invariant components of action events. In each of our clips, children saw the exact same path across varying manners or the exact same manner across varying paths – the invariant in each study was the semantic component that remained constant. In the real world, children rarely see such contrived scenes. Rather, children often see several different actors perform the same action at different points in time. These studies provide a first step in understanding the categorization of the semantic components path and manner by investigating children's ability to abstract an invariant action. Had children failed at these tasks, there would be little reason to move to more complex, naturalistic stimuli. Their success gives us reason to now explore the range of variability that infants can process and detect regarding categorization of path and manner.

In sum, research suggests that infants have the ability to perceive, process, and abstract four semantic components that are lexicalized in the English language, containment, support, path, and manner. Perhaps then, as some suggest (Gentner & Boroditsky, 2001; Mandler, 2004), infants do start their language learning with a set of privileged concepts used to make sense of events and spatial relations in the world.

Factors that Hinder or Support Infants' Abstraction and Categorization of Spatial Relations

Infants can form categories of spatial relations albeit with some categories coming in earlier than others. But, there is a catch. The knowledge they have is more fragile than it might first appear. For example, Baillargeon and colleagues (Aguiar & Baillargeon, 1999; Baillargeon, 2004; Hespos & Baillargeon, 2001a; 2001b; Wang, Baillargeon, & Paterson, 2005) report that young infants have great difficulty in generalizing what they know about occlusion, containment, and covering relations to new instances. Further, as Casasola and Cohen (2002) have shown infants were unable to form categories of either support or degree of fit when the objects used to portray the relation were not those that initially depicted the relationship. They are not able to form "abstract" spatial categories. This research suggests that extending (or generalizing) a relation to a new set of objects is a different task than forming an initial relational category. There is also evidence in the research on verb learning that children have difficulty extending their verbs as widely as adults do (Ma, Golinkoff, Shun, Brandone, Hirsh-Pasek, & Song, 2007; Seston, Golinkoff, Ma, Tomlinson, & Hirsh-Pasek, 2007). Other studies show that children have difficulty extending a newly learned verb to new referent actions (Forbes & Farrar, 1993; 1995; Maguire et al., 2002; Poulin-Dubois & Forbes, 2002). For instance, Maguire and colleagues found that 18-month-olds could not extend a novel verb to new agents.

These studies suggest that there is a developmental progression in children's ability to categorize and extend nonlinguistic spatial relations (Aguiar & Baillargeon, 1999; Baillargeon, 2004; Casasola & Cohen, 2002; Hespos & Baillargeon, 2001a; 2001b; Wang et al., 2005) as well as relations portrayed in action events and labeled by verbs (e.g., Forbes & Farrar, 1995). As Casasola (2005a) writes, "infants' initial reliance on familiar objects for recognizing a spatial relation eventually gives way to recognizing the relation with novel objects as well" (p. 279). At

first, infants' spatial categories are limited to the original objects and events that depict them. Only later are infants able to break away from these original objects and events and form abstract spatial categories. For example, the English spatial term on applies to the spatial relation of support, regardless of the objects that are used to depict that relation.

Casasola (2005a) investigated 14-month-olds ability to form an abstract spatial category for support. She was interested in looking at the impact of the number of category exemplars shown and children's ability to form relational categories. Infants who had habituated to only two exemplars were now able to categorize support, while those who were presented with six exemplars did not show evidence of the ability to categorize support. Casasola argued that infants failed to form a category of support in the six-exemplar condition because they were attending to the objects and not the relations, and because they did not have enough time to compare the relations. A parallel finding with verb learning is that of Maguire, Hirsh-Pasek, Golinkoff, and Brandone (2007). They found that 2.5- and 3-year-olds were able to learn and extend a novel verb to a new agent after they had seen a single actor but not after they had seen four actors.

Research has just begun to address the abstract spatial categorization of the semantic components path and manner. Pruden et al.'s (2004) research on infants' ability to abstract an invariant path and manner takes a first small step in addressing the question of whether infants can form categories of actions in motion events. Song, Golinkoff, Seston, Ma, Shallcross, and Hirsh-Pasek (2006) built on the Pruden et al.'s results and showed 10- to 12-month-old infants dynamic events of four different human actors either jumping or marching for familiarization. No language accompanied these events. Each actor marched or jumped in two different ways (e.g., across the scene versus up and down stairs visible in the scene). Results suggest that even

10-month-olds can form a category of a dynamic action event (marching vs. jumping) performed by different actors. Babies preferred to watch the familiar action at test when performed by a novel actor. Pruden (2007) also reported that babies were able to extend an invariant category to include a new agent at 10 months of age for path and 13 months of age for manner. Thus, the research beginning to emerge suggests that the categorization of dynamic action events may be present prior to the time that language comes on the scene. Only further work will tell whether the ambient language itself is playing a role in this categorization. The research to be reviewed below suggests that it might.

Can language help infants form dynamic action categories?

A large body of research on the role of language in object category formation already exists. This research generally shows that infants' object categorization is facilitated by use of a common label and that language heightens attention to objects (Balaban & Waxman, 1997; Baldwin & Markman, 1989; Booth & Waxman, 2002; Gentner & Namy, 1999; Gopnik & Nazzi, 2003; Namy & Gentner, 2002; Waxman & Markow, 1995). Very little is known about this same phenomenon in the realm of spatial discrimination and categorization. Would the addition of language aid infants' discrimination and categorization of spatial relations? Two possibilities exist.

First, the addition of language to previous categorization tasks could heighten attention to spatial relations and facilitate categorization as it does in object categorization studies. Support for this hypothesis comes from the literature that shows that labels help infants form categories of objects (Balaban & Waxman, 1997; Waxman & Markow, 1995). Second, the addition of language could disrupt performance in spatial discrimination and categorization tasks as the introduction of language may increase the processing demands. This possibility is supported by

Stager and Werker's research (1997). In a non-linguistic discrimination task, 14-month-olds could discriminate between two minimal pair phonemes (/b/ vs. /d/). However, they were only able to do so when the phonemes were presented in the absence of an object. The addition of an object increased the processing demands of the task and caused infants to fail to discriminate. Several studies have already been conducted to test this empirical question.

Casasola (2005b) tested whether language would facilitate the formation of an abstract spatial category of support. Using the same design/stimuli as those used in Casasola and Cohen (2002), she found that infants were able to form a category of support when the familiar word on accompanied the habituation events. Thus, the addition of a familiar word can aid in the formation of abstract spatial categories.

Pulverman, Brandone, and Salkind (2004) also examined the role of language in the processing of motion events. Using the same events from Pulverman et al. (2003), language was added to see if 14- and 17-month-old infants' processing of path and manner would be influenced. Results indicate that English-learning infants who heard a novel verb label during habituation noticed the manner of motion more when compared to those infants who participated in the original, non-linguistic version of this study. Infants who heard the novel verb label during habituation did not however increase their attention to the path of the agent. It appears that when English-learning infants hear a novel verb label while watching an event, they increase their attention to the manner of the motion. These results suggest that the addition of language to this task makes a difference by guiding infants' event processing. Furthermore, not just any label will do. This result vanishes when a noun label is used, suggesting that children are sensitive to form class of the novel word that accompanies the visual displays (Pulverman, Golinkoff, Hirsh-Pasek, Brandone, & Seston, 2006). These studies show that the introduction of a label

differentially heightens attention to semantic components, while Casasola and Cohen's (2002) research suggests that labels facilitate the formation of the spatial category, support. Does a common label also facilitate the abstraction of path or manner in those infants who were previously unable to do so (Pruden, 2007; Pruden et al., 2006)?

Pruden et al. (2004) found that infants younger than 10 months of age could not abstract an invariant path in a series of motion events, and that infants younger than 13 months of age could not find an invariant manner. Furthermore, in both studies, 7- to 9-month-old infants were unable to abstract an invariant path and invariant manner. This failure provides us with the opportunity to test whether the addition of language can assist in categorization of these action components. Using the same procedure and stimuli, Pruden et al. (2006; Pruden, 2007) added a label during familiarization to see if it would help infants abstract an invariant semantic component.

In the path study, we familiarized infants to four motion events each depicting the same path (e.g., "over"), but varying manner (e.g., "flapping", "spinning", "twisting", "bending") accompanied by the novel verb label "javing". At test, infants were simultaneously shown a familiar event (i.e., familiar path, novel manner; "toe-touching over") and a novel event (i.e., novel path, novel manner; "toe-touching under") in silence. We predicted that if infants could abstract an invariant path, they would have a significant preference for one of the test events. The results were striking. Seven- to nine-month-olds benefited from the addition of a common label, showing a significant preference for the novel test event (e.g., "toe-touching under") at test. The inclusion of language appears to facilitate the abstraction of path.

In the second study, 7- to 9-month-olds viewed four familiarization events, each depicting the same exact manner across varying paths (e.g. "spinning over", "spinning around",

"spinning behind", and "spinning past"; Pruden et al., 2006; Pruden, 2007) and accompanied again by the novel verb label "javing" (repeated a total of 16 times). At test, infants were presented simultaneously with the familiar manner/novel path and a novel manner/novel path (e.g., "spinning under" vs. "twisting under"). Unlike the path study, infants did not show a significant preference for either test event. Infants were not able to use the common label to abstract the invariant manner. However, perhaps further research will reveal that 10- to 12-month-olds profit from the addition of language. Recall that manner abstraction did not occur until 13 months in the original research without language (Pruden et al., 2004).

Taken together, the results from both Pulverman et al. (2004) and Pruden et al. (2006; Pruden, 2007) suggest that, as in the object categorization tasks, labels heighten attention to features of actions within events. However, labels may not always help. For Pruden et al's (2006) 7- to 9-month-olds, the presence of a label helped them abstract a path, but not a manner. Language appears to differentially affect infants' abstraction of semantic components. On the one hand, it appears that language plays a special role in helping infants abstract semantic components. On the other hand, this facilitative effect appears to be limited at present to only one semantic component, path. There is reason to believe that path may be more fundamental in learning about the world (Mandler, 2004; Pruden et al., 2004) and earlier expressed in language than manner (Naigles et al., 1992; Zheng & Goldin-Meadow, 2002). Perhaps then, abstracting path is easier and requires less attention than abstracting manner.

Bringing it All Together: Events, Actions, and Spatial Relations in Infancy

What have we learned about how infants and young children perceive and categorize the events that will be encoded by their language? This review has focused specifically on the underpinnings for the learning of verbs and spatial expressions, as it is these parts of language

that routinely label events or their outcomes.

First, we have found through our review that there is a developmental trend in the ability to process and categorize events. Research shows different semantic components are processed and abstracted at different points in development. For example, Casasola and colleagues (Casasola & Cohen, 2002; Casasola, Cohen, & Chiarello, 2003) demonstrated the ability to form categories of spatial relations develops at different times for different spatial relations. Infants could form categories of the spatial relation containment before they could form categories for the spatial relations support. Finally, in related research, Baillargeon (2004) showed that infants pay attention to different perceptual features within different types of spatial relations. In these studies, 4.5-month-olds could reason about occlusion relations when they were given height information, but were unable to use this same information to reason about containment relations until 7.5 months of age.

Pruden et al.'s (2004) findings suggest that the categorization of semantic components, like path and manner, does not come online at the same time. Infants abstract invariant paths across varying manners before they can abstract invariant manners across varying paths. These results, along with Pulverman et al.'s (2003; 2004), suggest that the semantic component path might be more fundamental than manner in building a conceptual foundation for verb learning. On the other hand, the research of Song et al. found that infants could abstract a category of manner at 10 to 12 months of age, several months earlier than Pruden et al. (2004). The reason for these differences is unclear, indicating that we are just at the beginning in understanding the factors that facilitate or impede the categorization of actions. Nor did Song et al. (2006) test for path categories. Prior work by Pruden et al. suggests that had Song and colleagues tested for path categorization, perhaps they too would have found path emerging prior to manner.

Why does path seem to be consistently favored over manner in the studies that test for both? One possibility is that path is more perceptually salient than manner. This account is supported by numerous findings. For example, Maguire (2003; Maguire et al., 2003) found that English-speaking children under 3 years of age willingly attach a novel verb label to the path rather than to the manner of action. Even when provided with additional syntactical information (e.g., "Starry is blicking over the ball), only those children with a large arsenal of relational terms (e.g., above, on, kick, tickle) behaved like native English-speaking adults and attached the label to the manner of action. Further, research by Pulverman and colleagues (2003) demonstrated that 14- to 17-month-olds, with a rich vocabulary, were more attentive to manner changes than their low vocabulary counterparts. These studies demonstrate that children are initially biased to attend to and label path, an argument consistent with Mandler (2004) who views path as one of the conceptual primitives needed for the conceptual development of motion. As Mandler writes, "…PATH is the simplest conceptualization of any object following any trajectory through space" (p. 28). Perhaps then, it is more important to know where you are going, your path, rather than how you got there, your manner. Thus, it should thus come as little surprise that path seems to be processed and abstracted before manner.

The second thing that we have uncovered is that there are factors that can facilitate the categorization of dynamic events. In particular, the use of a language overlay seems to heighten attention to some components of events over others (Pulverman et al., 2004) and to facilitate event categorization (Pruden et al., 2006; Pruden, 2007). There is little understanding at present of the mechanism that is involved in this facilitation. It may be purely attentional, in that a consistent sound may cause children to watch an object or event more closely (Baldwin & Markman, 1989; Kaplan, Fox, Scheuneman, & Jenkins, 1991; Mendelson & Haith, 1976). In this

case, musical notes might facilitate dynamic category formation in the same way. Or, language itself may be as Roger Brown (1958) argued long ago, "an invitation to form categories". By its sameness, it may be indicating that the diverse exemplars over which it is used share important similarities as well, a position espoused in somewhat different ways by Waxman and colleagues (Balaban & Waxman, 1997; Waxman & Markow, 1995). Clearly there is much more to be done in understanding how infants form nonlinguistic event categories that will ultimately by encoded by their native language.

Conclusions

To understand how relational terms are learned in young children investigations of the conceptual foundation of verb learning are essential. As this chapter demonstrates, we are only just beginning in our ability to comprehend how infants process and detect actions within events. How do infants' perception and conception of events map onto the world's languages? How do children learn to attend to the particular semantic components their language favors?

Much of the work done on infants' event processing has only examined a very small slice of events – motion events. Despite the limited amount of research on event processing in infancy, we are already starting to see clear evidence that infants can process key aspects of motion events. For example, we now have evidence that infants can at the very basic level process, abstract, and categorize those spatial relations that make up motion events. Impressively, infants in the first year of life show the burgeoning ability to discriminate and categorize the kinds of relations, including *containment*, *support*, *path*, and *manner*, that are codified in the languages of the world (Casasola, 2005a; Casasola & Cohen, 2000; 2002; Casasola et al., 2003; Choi et al., 1999; Hespos & Baillargeon, 2001a; 2001b; Pulverman et al., 2003; Pulverman & Golinkoff, 2004; Pruden et al., 2004; Pruden et al., 2006).

This brings us back to the question of why are verbs so much harder to learn than nouns. Researchers argue that it is not the conceptualization of actions and events that makes learning relational terms so difficult (see Maguire & Dove, this volume; also see, Gentner, 1982; Gentner & Boroditsky, 2001; Hirsh-Pasek & Golinkoff, 2006; Snedeker & Gleitman, 2004). Indeed, our research suggests that children have many of the prerequisite abilities needed to map relational terms onto actions. Gentner (1982) hypothesized that the problem in verb learning is with packaging relations and mapping words onto relations (see Maguire & Dove, this volume, for a more thorough discussion; Maguire et al., 2006). The research we present here supports this hypothesis. Infants are capable of making sense of the world of both objects and events. At the very least infants are sensitive to the spatial relations and actions embedded in events and encoded in relational terms. Despite the fact that the study of how infants view dynamic stimuli is so young, the good news is that infants are interpreting the current events in their world.

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