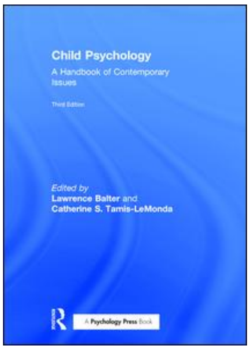

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Language Acquisition

From Words to World and Back Again

Amy Pace, Dani F. Levine, Giovanna Morini, Kathy Hirsh-Pasek, and Roberta Michnick Golinkoff

INTRODUCTION

Imagine an infant visiting the zoo with her mother. From her stroller, she observes a troop of capuchins on a nearby tree. Her mother points to the scene and says, "Look! The monkeys are grooming each other!" How might she come to understand that her mother's arbitrary auditory signals represent something about a scene that she is witnessing? How does she parse the continuous actions of the apes to derive appropriate units of meaning such as *agents* or *actions* from this complex, dynamic event? And how might she make the correct assumptions about how the words relate to the unfolding events before her? Despite recent advances, much of the current debate centers on the classical questions of how infants map words onto the dazzling array of sights and sounds in their world and how this process is guided by development and experience. Indeed, the field is still pondering possible solutions to the problem of ambiguity or indeterminacy of reference that was introduced by Quine in 1960 as a philosophical conundrum. Given the complexity of the world, how is a language learner to know that a foreign word such as *gavagai*, uttered while a rabbit scurries by, refers to the entire rabbit rather than to the fur, ears, or ground on which it thumps. With no constraints guiding the learner, would she ever converge on the correct mapping of word to world?

This example from Quine helps to illustrate why the seemingly simple task of word learning (let alone grammatical learning) that takes place in homes and villages around the world is deeply complex. Even if she has mastered the sound system of her native language—even if she can pluck well-formed words from the constant stream of input—our infant at the zoo still must discern that her mother is referring to the capuchins (not their tails or ears), and recognize that the verb *groom* encompasses an entire set of social behaviors (including the specific actions of picking, combing, and scratching). Moreover, infants must "read" the social cues suggesting that mom is referring to those monkeys and not to the many other interesting events that are simultaneously playing out in the zoo scene such as the branches swaying or the leaves rustling. Finally, if the baby is to successfully use this vocabulary in new contexts, she must eventually understand that these words are not unique to this time and place but can be generalized to other scenarios that may be perceptually distinct (e.g., the prom queen who is impeccably groomed or the employee groomed to take over the company).

This chapter is a brief review of the latest thinking in the problem of language development. Though there is only space for a "speed dating" approach to the literature, we hope to unveil the complexity of language learning and to celebrate the many advances that have been made in the last 25 years. Simply put, language learning requires an understanding of the sound system (or sign system for deaf individuals), the world of objects, actions and events, and the ways in which units like words and grammar map between sound and world.

After setting this work in historical context through the theories of language development, we address language acquisition in three sections. First, we explore how infants parse the relevant acoustic units from the continuous stream of ongoing speech. Next, we consider how infants perceive, discriminate, and categorize the world of objects, actions, and events. Finally, we address the mapping problem: how do children learn to deftly move from words to world and back again? Throughout, we adopt a dynamic and developmental perspective suggesting that the task is achieved through attention to multiple inputs that children integrate as they come to rely jointly on perceptual, social, and linguistic cues. The challenge for the field moving forward is to give more than lip service to an integrative multi-cue system and to specify exactly how each of these cues relates to language learning over time. The field has only recently begun to meet that challenge (Christiansen, Conway, & Curtin, 2005; Curtin, Byers-Heinlein, & Werker, 2011; Curtin & Werker, 2007; Hirsh-Pasek & Golinkoff, 1996; Hollich et al., 2000; Golinkoff, Hirsh-Pasek, & Hollich, 1999; Plunkett, 2001; Reeder, Newport, & Aslin, 2013; Waxman & Lidz, 2006; Werker & Curtin, 2005).

HISTORICAL CONTEXT

Theories of Language Acquisition

A number of theories have emerged to explain language development—some starting with the Quinean dilemma and some forcefully rejecting it. Each, however, brings a unique perspective and historical context to the study of how infants succeed in mapping words (or grammar) to world. Most theories continue to adopt a narrow view of acquisition, emphasizing the role of a particular process or mechanism over others. These come in a number of varieties, from those that are more perceptually grounded and bottom-up in orientation, to those that are more nativistic, to those that offer what some have called a "radical middle" (Golinkoff & Hirsh-Pasek, 2006).

From the bottom-up persuasion, perceptual accounts purport that statistical learning mechanisms can largely explain the cross-situational mapping of sounds to meanings and that the system of language learning can be based on statistical co-occurrences (Smith, 2000; Smith & Yu, 2008; Yu & Smith, 2007; Yurovsky, Fricker, Yu, & Smith, 2014). That is, infants can detect statistical regularities in input, recognizing, for example, that the spoken word "monkey" reliably occurs in the presence of the visually observed animal monkey, not in the presence of a giraffe. Studies from Linda Smith's laboratory provide an excellent window into research from this perspective. As infants discover regularities in the input they hear, the mapping between word and world is constrained. Landau, Smith, and Jones (1988; Gershkoff-Stowe & Smith, 2004), for example, suggested that children develop a *shape bias* on the assumption that as a first guess, things that have the same shape tend to have the same name. Indeed, they have even traced the development of the shape bias from early attention to visual cues to its full flown form (Smith, 2009; Yee, Jones, & Smith, 2012). This theory offers a perceptually driven approach to how children develop strategies for word learning. Newer instantiations of the theory also speak to the confluence of social, cognitive, and perceptual cues in building effective word to world mappings (Pereira, Smith, & Yu, 2014). A tremendous amount of data supports this theory, though it better explains how our young child at the zoo would learn the word for an object like *monkey* than it would for the event of *grooming* (a verb) which lacks any definable shape (but see Hard, Recchia, & Tversky, 2011; Golinkoff, Chung, Hirsh-Pasek, Lui, Bertenthall, Brand, Maguire, & Hennon, 2002; Kersten, Smith, & Yoshida, 2006; Maouene, Laakso, & Smith, 2010). Other critics suggest that children would do better to rely on the object function than the object shape for mapping, even though shape is often a proxy for function (Kemler-Nelson, Russell, Duke, & Jones, 2000). For example, hammers, not pliers, look like the kinds of things that bang in nails. Finally, Waxman notes how these pure perceptual tabula rasa views of the young child have been questioned in the literature (Waxman, 2004; Xu, 1999).

Social-pragmatic accounts, in contrast, hold that social interactions drive language development by increasing children's attention to the communicative context and others' intent to name specific objects or events (Baldwin, Bill, & Ontai, 1996; Booth, McGregor, & Rohlfing, 2008; Diesendruck, Markson, & Bloom, 2003; Goldstein & Schwade, 2008; Poulin-Dubois & Forbes, 2006; Tamis-LeMonda, Kuchirko, & Song, 2014; Tomasello, 2000). Contemporary research from this perspective builds on Bruner's (1983) work detailing the crucial role of caregivers who provide the requisite scaffolding for language acquisition (see also Vygotsky, 1978). With the child constrained by social cues, she knows where to attach the label being offered. Historically, this approach was endorsed by Katherine Nelson (1988) who wrote,

> The typical way children acquire words . . . is almost completely opposite of the Quinean paradigm. Children do not try to guess what it is the adult intends to refer to: Rather . . . it is the adult who guesses what the child is focused on and then supplies the appropriate word.
>
> (p. 240–241)

Bloom (1993) sympathizes with this perspective and uses an example from Fauconnier (1985) to illustrate the role of the social partner in guiding word learning to the most relevant object (Bloom, 2000) from the top down. As Fauconnier noted,

> . . . the potential of a sentence is always far less than its general potential for all possible configurations. (A brick could theoretically occupy any position in a wall, but at any stage of the actual building process, there is only one place for it to go.)
>
> (p. 168–169)

Today, there is abundant support for the importance of social cues in language acquisition. An outstanding review by Tamis-LeMonda and colleagues (2014) demonstrates how joint engagement and temporally contingent, semantically relevant responsiveness from a social partner are all predictive of later language growth—presumably because they assist children in the mapping process (see also Adamson et al., 2012; McGillion et al., 2014; Tomasello, 2000, 2003). It should be emphasized that social-pragmatic views are often considered quite complementary to statistical learning theories. In fact, verbal contingent input from parents may capitalize on infants' statistical prowess since it increases the likelihood that the words children hear refer to what is salient to them and the focus of their attention

(Tamis-LeMonda et al., 2014). Though there is ample evidence to endorse this view as well, the research is limited by the fact that most of the word-to-world mapping scenarios examined have been for clearly delineated objects that map onto nouns. Further, it is unclear how social cues can help the child resolve whether the word is meant to label the whole cup or just the handle. For example, pointing to a distal object (a social cue) can only go so far in disambiguating the label's focus.

Syntactic bootstrapping breaks from those theories by suggesting that external cues drive mapping. First articulated by Gleitman (1990), this perspective holds that children are deeply sensitive to grammatical structure, which in turn supports children's inferences about lexical meaning (Bowerman, 1990; Gertner & Fisher, 2012; Fisher & Song, 2006; Gleitman, 1990; Gleitman, Cassidy, Nappa, Papafragou, & Trueswell, 2005; Hirsh-Pasek & Golinkoff, 1996; Naigles, 1990). Fisher's work offers a wonderful illustration as it documents that even 15-month-olds can use sentence structure cues to interpret "who is doing what to whom" for unfamiliar verbs. When babies heard "He's *kradding* him" they looked longer at a two person event in which one person is doing something to another, than when they heard, "He's *kradding*" (Jin & Fisher, 2014; see also Hirsh-Pasek & Golinkoff, 1996). This suggests that at this tender age, infants are already using grammatical structure to bootstrap the meaning of a word. This is the youngest age at which there is evidence of young children using grammatical cues to map words onto events and represents a relatively new and promising area for word learning.

To more fully explain the ways in which grammar might constrain word mapping, Gillette, Gleitman, Gleitman, and Lederer (1999) created what they called the *Human Simulation Paradigm*, which asked a group of adults to guess the target word used by a parent when she was addressing her child. They cleverly put a *beep* sound over either the noun or verb the mother said. Even adults had trouble guessing verb meaning unless they were provided with syntactic context that reinforced what the referent of the verb might be. This demonstration offered a proof of the concept that context alone—be it perceptual or social—is not enough to guarantee mapping in a complex world. Recent research using this paradigm reminds us that a mother's referential transparency also exerts some influence on mapping; adults are more likely to guess the target word correctly if it is clear what the perceptual and social cues indicate (Cartmill, Armstrong, Gleitman, Goldin-Meadow, Medina, & Trueswell, 2013; see also Song, Baillargeon, & Fisher, 2014).

Finally, a number of top-down approaches adopted what were called *constraint-based models* to account for word to world mapping. These views offered a set of particular word learning biases that limit the potential hypothesis space for novel words (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Markman, 1989; Markman, 2014; Markman, Wasow, & Hansen, 2003; Soja, Carey, & Spelke, 1991; Woodward & Markman, 1998). For example, one recommended bias was called the *whole object assumption* (Markman & Hutchinson, 1984). Answering Quine directly, this principle posits that the language learner who sees that rabbit hopping by would do best to assume that the word *gavagai* referred to the whole rabbit. While these theories offered a way out of the reference problem, they were also critiqued as crediting too much capability to the young child (Halberda, 2003). As with the other theories, this account of the mapping problem was largely fixated on object to noun mapping. Waxman (2004; Arunachalam & Waxman, 2014; Waxman & Lidz, 2006), however, argues that the focus on early noun learning might be prudent, as it offers a toehold into the system from which young children can use grammar to differentiate other word forms and their place in the evolving grammar.

Throughout the 1980s and '90s many fought to defend their theory as *the* predominant explanatory mechanisms for language learning. In the last 15 years, however, most have relaxed their views and written about the need for theories that integrate perceptual, social, constraint, and grammatical accounts. The Emergentist Coalition Model (ECM) was the first of these. Introduced by Hirsh-Pasek and Golinkoff (1996; see also Golinkoff et al.,1999; Hollich et al., 2000), it offers a developmental systems-based framework to explain how infants might use a multitude of inputs that were differentially weighted across developmental time. Under this view, a child might start the process of word learning with a kind of associative strategy *à la* Landau et al. (1988; see also Pruden, Hirsh-Pasek, Golinkoff, & Hennon, 2006), but increasingly rely on social inputs before integrating grammatical cues to word meaning (see also Hoff & Naigles, 2002).

Variations of the hybrid theme have been broadly adopted (e.g., Booth & Waxman, 2008; Namy, 2012). Some agree that infants initially rely upon associative properties (e.g., Smith, 2000) and gradually gain insight into language-specific cues that bolster language acquisition (Regier, 2005; Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002). Aslin (2014) builds on this theory, suggesting that both language-specific and domain-general constraints guide associative word learning. Probabalistic learning theories (e.g., Connectionist and Bayesian models; Dynamic Systems Theory) propose that language acquisition emerges from the moment-to-moment interaction of general knowledge (i.e., of word-to-world mappings in language) and a multitude of factors within and across word-learning contexts (Christiansen et al., 2005; Elman, 2009; Frank, 2014; Frank, Goodman, & Tenenbaum, 2009; Perfors, Tenenbaum, Griffiths, & Xu, 2011; Thelen & Smith, 1994; Yu & Ballard, 2007). Christiansen and Monaghan (2006; Monaghan & Christiansen, 2014), for instance, suggest that children track distributional information about the co-occurrence of words, their phonological sound properties, and their situational context, and combine these cues through a mechanism of "multiple cue integration" to discover reliable evidence about linguistic structure that is unavailable in any single source.

The move towards models of word learning with multiple inputs that interact over time has already begun in earnest. These theories all focus on the same puzzle that has captivated philosophers like Plato over the centuries. How is it that we figure out what the father of our field simply titled *Names for things* (Brown, 1973)? While our theories focus squarely on the mapping problem as a context for language learning, this process of mapping itself rests on the *a priori* assumptions that infants can pluck meaningful units from the fast-paced sounds that flow by in the melodies of language input (or of course the hand movements for those who are surrounded by sign language) and that they singularly notice the objects, actions, and events that mark the continuous stream of experience. In the next sections we speak to recent findings in each literature and reveal the often remarkable progress that infants make in the first years of life.

THEORETICAL AND EMPIRICAL CONSIDERATIONS

Decoding the Speech Stream

Infants Prefer Language

Infants are eavesdropping on their parents' voices even before they are born (Kisilevsky et al., 2003, 2009; see also Smith, Dmochowski, Muir, & Kisilevsky, 2007). In utero they not only recognize the melodies of speech, but also musical melodies that sound speech-like (Granier-Deferre, Bassereau, Ribeiro, Jacquet, & DeCasper, 2011). After birth, infants are sensitive to the same patterns of voices, and even speech passages, heard amidst the backdrop of a mother's pounding heart and through the amniotic fluid (DeCasper & Fifer, 1980; DeCasper & Spence, 1986; Fifer & Moon, 2008; Kisilevsky et al., 2009). Babies are sensitive to the patterns of their native language (for a review, see Gervain & Mehler, 2010) and can make accurate phonetic distinctions between sounds (e.g., "*ba*" vs. "*pa*"; Bertoncini, Bijeljac-Babic, Blumstein, & Mehler, 1987)—even in languages to which they have never been exposed (Eimas, 1975; Kuhl 1987). There is evidence that hearing babies can even make phonetic distinctions at 4 months of age in *sign* language (Baker, Golinkoff, & Petitto, 2006; Palmer, Fais, Golinkoff, & Werker, 2012) and prefer to look at sign language rather than nonlinguistic gestures at 6 months of age (Krentz & Corina, 2008).

From the beginning, infants are more attuned to human language over an artificial language that mimics language's properties (Vouloumanos & Werker, 2007); over complex noise that maintains the frequency and spectral power of a word (Travis et al., 2011); and prefer human voices to macaque vocalizations (Shultz & Vouloumanos, 2010). As children hear more of the contrasts in their native language, they move from language generalists to specialists, narrowing their discrimination of the phonemes such that an English-reared infant might at first distinguish among African click sounds and the pre-vocalized Bs of Spanish and later move to a heightened focus on the Ps and Bs that occur in English (see Maurer & Werker, 2014, for a review). This fine-tuning of speech perception in infancy predicts language development in the second year of life (Cristia, Seidl, Junge, Hagoort, & Soderstrom, 2014; Newman, Ratner, Jusczyk, Jusczyk, & Dow, 2006; Tsao, Liu, & Kuhl, 2004).

Parents help infants tune in to speech by using a different language register with babies than they do with adults (Cooper & Aslin, 1990). Known as infant-directed speech (IDS), this register is characterized by exaggerated, sing-song intonation, more pauses between clauses (Broen, 1972), and high-pitched speech (Fernald & Mazzie, 1991; Soderstrom, 2007). Infants show a strong preference for listening to this type of language input compared to adult-directed speech (ADS, Cooper & Aslin, 1990; Fernald, 1985). Input marked by IDS has been linked to many positive language outcomes, including better speech perception (Liu, Kuhl, & Tsao, 2003; Tsao, Liu, & Kuhl, 2004; Werker et al., 2007), improved word segmentation (Thiessen, Hill, & Saffran, 2005), and larger vocabularies (Gleitman et al., 1984; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Masur, 1982; Rowe, 2008; Tomasello, 1988). At 21 months, children learn words more readily if they are presented in IDS rather than ADS (Ma et al., 2011). IDS appears to facilitate language growth in a number of ways, possibly because it heightens the perceptual features of language, making it easier for babies to find the regularities.

Finding the Patterns

Attending to perceptual features within the speech stream is only the beginning of the process. To map word forms to sounds, infants must detect patterns in the input they hear and hook those patterns to the objects, actions, and events they see. A plethora of research speaks to the mechanisms that infants might use to construct words from syllables. Sensitivity to the predominant stress patterns a language uses is one way infants identify word boundaries. For instance, since English uses trochaic (strong-weak) stress, a heavy syllable provides a reliable cue to the beginning of a word (Jusczyk, Houston, & Newsome, 1999; Nazzi, Dilley, Jusczyk, Shattuck-Hufnagel, & Jusczyk, 2005). New findings suggest that infants routinely attend to features at utterance edges to segment words from fluent speech as early as 6 months (Johnson, Seidl, & Tyler, 2014).

Another way to find the words is to use statistics. In a classic study, Saffran, Aslin, and Newport (1996) suggested that statistical learning provides a mechanism for both segmenting the speech stream and for identifying combinatorial cues to word forms. Two minutes of an artificial, monotone speech stream was presented to 8-month-old children. Using transitional probabilities that were nested in the stimuli, infants accurately distinguished whole words (three-syllable trigrams) from part words. For example, when hearing *bubidakupadotitabidakubupati*, some of the sounds followed others 100% of the time (e.g., *bida*—analogous to a combination of sounds within a word in normal speech, and part of the nonsense word *bidaku*); others did not. Remarkably, with this short exposure, infants could find the syllables that hung together statistically from those that did not.

Infants also use frequent words like their own name or Mommy to segment the speech stream. They can recognize words that come after these familiar words after but a brief exposure to a 6-sentence passage (Bortfeld, Morgan, Golinkoff, & Rathbun, 2005).

The use of stress patterns, statistical learning, and frequent words demonstrated that infants could abstract patterns from the input and build up a representation of word forms. Babies of the same age were also shown to isolate broader speech units. By 7–10 months, for example, infants display preferences for speech with pauses inserted at clausal boundaries over speech that contains pauses within syntactic units, and they do so in their home or a foreign language (Hirsh-Pasek, Kemler Nelson, Jusczyk, Cassidy, Druss, & Kennedy, 1987). This suggests that they are "hearing" the natural breakpoints in speech that will allow them to add the figurative commas and periods to the language melodies surrounding them. Sensitivity in slightly older children extended to phrasal breaks as well. Using a head-turn preference paradigm, 11-month-olds preferred to listen to speech in which one-second pauses were placed at the end of a noun or verb phrase rather than within the unit. Impressively, IDS, but not ADS, seems to assist infants in this segmentation as the "prosodic qualities of motherese provided subjects with cues to units of speech that corresponded to grammatical units of language" (Kemler-Nelson, Hirsh-Pasek, Jusczyk, & Cassidy, 1989; see Jusczyk, Hirsh-Pasek, Kemler-Nelson, Kennedy, Woodward, & Piwoz, 1992, for a review).

Taken together, then, the research suggests that infants in the first year of life can analyze the speech that envelops them. They know when speech is directed at them from the use of speech registers like IDS, they note the patterns within the sound stream, and they are constantly assembling and reassembling the sounds of the language at both the micro and macro level to isolate word forms and phrases that will be mapped onto objects, actions, and events.

Of course, infants will need to dissect the event stream into the units of meaning that are represented by those word forms. Although we know a great deal about infants' remarkable understanding of objects (see Santos & Hood, 2009, for a review; Baillargeon & Carey, 2012; Fields, 2013; Hespos & Baillargeon, 2001; Mervis, 1987; Needham & Baillargeon, 1993; Spelke, Kestenbaum, Simons, & Wein, 1995; Xu, 2013) and how this may contribute to learning object labels like concrete nouns (Gopnik & Meltzoff, 1987; Merriman, Scott, & Marazita, 1993; Smith, 2013), we know less about how infants carve dynamic events into the components that will be labeled by relational words such as verbs and prepositions. Due to space constraints, our next section focuses on how infants decipher the continuous ebb and flow of action that comprises everyday events in the infant's world. This area of research is in its infancy, but suggests a developmental trajectory similar to that of word segmentation.

What Do Infants Know about Parsing Events for Language?

A prototypical event includes canonical entities such as *agents* performing *actions* with *objects* to produce *outcomes* (Nelson, 1986; Zacks & Tversky, 2001), as in "the mother pushed her infant in a stroller to see the monkeys at the zoo." Focusing specifically on motion events, Talmy (1983, 1985) outlined a number of components that describe the relations codified across languages (see also Chomsky, 1981; Johnson, 1987; Lakoff, 1987; Langacker, 1987). Among them are *path* (the trajectory of motion); *manner* (how the motion is performed);

figure (the moving agent or object); *ground* (the reference entity or stationary setting); and often *source* (beginning point of an event) and *goal* (end point of an event). This list, though hardly exhaustive, gives us a sense of the puzzle that infants need to solve as they break apart events into the units that will be mapped onto word forms and sentences.

Do infants detect these kinds of units in the temporal and spatial flow of events? Mandler (1988, 1992, 2004; Mandler & Pagán Cánovas, 2014) suggests that they might. Specifically, she theorized that in the case of both objects and events, preverbal concepts are derived from a finite set of spatial primitives rooted in salient spatial information, much of it motion based (Mandler, 1992, 2004). Critically, the verbs and prepositions that encode these image schemas allow us to describe *relations* between objects and participants in events (e.g., "the capuchins are *in* the tree" or "the monkeys *groom* each other"). These relations are the crux of language, permitting us to comment on the world's events.

Our own work in this relatively unexplored area uses Mandler's intuitions and Talmy's categories as a starting point towards understanding how infants might detect language-relevant units in events. Although the analogy is imperfect, infants' ability to make sense of the external world traces a similar trajectory to the perceptual refinement observed as infants sharpen their sensitivities to native phonemic contrasts while decreasing responsivity to sounds that do not occur in their ambient language. In a loose analogy, events seem to be like this too: they appear to contain a universal set of potential components encoded differently across languages (Bowerman & Levinson, 2001; Golinkoff & Hirsh-Pasek, 2008). For example, in the sentence "Bill ran out of the house," *Bill* is the figure, *ran* is the manner, and *out of* is the path of the event. In English, the manner of motion is frequently conflated in the main verb (*run*), whereas the path is expressed in a "satellite" prepositional phrase (*out of* the house). In contrast, a verb-framed language such as Spanish conflates the path of motion with the main verb and expresses the manner optionally in a subordinate verb or adverbial phrase (e.g., *Bill salió de la casa corriendo*, which translates to "Bill exited the house running").

Children learn to divide the events in their world into categories that are language-specific (Parish-Morris, Pruden, Ma, Hirsh-Pasek, & Golinkoff, 2010; George, Göksun, Hirsh-Pasek, & Golinkoff, 2014), but the field is just learning about the developmental mechanisms that support this process. Recent research suggests that infants initially attend to both native and non-native components of events and that language input heightens or dampens attention to specific components as children learn to "package" this information according to the guidelines of their ambient language (Göksun et al., 2010; Golinkoff & Hirsh-Pasek, 2008; George et.al, 2014). Göksun and colleagues (2010) refer to this pattern as "trading spaces" and suggest that this process reflects preferences for certain event components over others when language butts up against the basic conceptual system.

Infants Process Dynamic Event Constructs

Well before infants can produce a single meaningful utterance, they attend to the activities and events in their world. As a window into what prelinguistic infants understand about the actions and movement they observe, our laboratories explore the ability to attend to, discriminate, and categorize event constructs within dynamic events (Pulverman, Sootsman, Golinkoff, & Hirsh-Pasek, 2003; Pulverman, Hirsh-Pasek, Golinkoff, Pruden, & Salkind, 2006). To date, the field has focused its attention on four closely examined constructs: containment-support; path-manner; figure-ground; and source-goal. These constructs are ideal candidates for investigation because they are central to language processing (Talmy, 1985). In addition, they share three key features (Golinkoff &

Hirsh-Pasek, 2008). First, each construct is perceptually accessible to infants (Mandler, 2004). Second, each construct is universally codified across languages and expressed linguistically (Talmy, 1985). And third, there is variation in the way different languages encode these constructs. Since we are concerned with dynamic spatial relations, we focus below on recent evidence from the exploration of infants' knowledge about path-manner and figure-ground. For space reasons, we bypass the story of source-goal (Bowerman, 1996; Lakusta, Wagner, O'Hearn, & Landau, 2007; Regier & Zheng, 2003) as well as static spatial relations, including containment-support (see Göksun et al., 2010, for a review; Baillargeon & Wang, 2002; Bowerman & Choi, 2003; Casasola, 2005; Choi, 2006; Hespos & Spelke, 2004; McDonough, Choi, & Mandler, 2003), though we recognize the incredible work of our forbears in setting the stage for the research we present in this chapter.

Path and Manner

Path is defined as a figure's trajectory through space, and manner refers to how the action is performed. Critically, both the figure's path and its manner of action are conflated within a single event, but languages package these features differently, as in the above English and Spanish examples in which Bill is running out of a house. Do infants attend to *path* and *manner* changes within dynamic events? To investigate this question, Pulverman and colleagues (Pulverman, Song, Pruden, Golinkoff, & Hirsh-Pasek, 2013) habituated English-reared 7- to 9-month-olds to a motion event in which the same starfish character performed both a manner (e.g., *spinning*) and a path (e.g., *over*), and then tested infants on events that changed the manner, path, both, or neither. Looking times indicate that infants readily detect changes in events with differing manners (e.g., *spinning* vs. *bending*) and differing paths (e.g., *over* vs. *under*) by 7 months, but that the ability to represent these constructs as independent features as they will be required to do for language will not be developed until 14 months of age (Pulverman et al., 2008).

Of course, merely identifying a unit within an event will only partially prepare children to learn a language. Language maps onto *categories* of events—paths like over, under, and through—rather than to individual paths like 3 inches over the ball. When does the ability to form categories that represent path and manner emerge? Recent findings indicate that by 10–12 months, infants are attuned to changes in events that cross category boundaries; they do not perk up to changes in individual paths—like 3 inches over the ball—that do not alter category membership (Roseberry, Göksun, Hirsh-Pasek, & Golinkoff, 2012). At the same time, English-learning infants can categorize an invariant path (e.g., *behind*) when the manner of motion changes (e.g., starfish *twisting*, starfish *bending*; Pruden, Roseberry, Göksun, Hirsh-Pasek, & Golinkoff, 2013; Figure 3.1), and this result disappears when the ground object (the ball) is removed. This indicates that the infants were not simply attending to the *trajectory* of the path, but were actually attending to the *relation* of the figure (starfish) and its movement with respect to a ground object. It takes a bit longer to form a category of manner. By 13 to 15 months, infants can categorize *manners* of motion across events that vary the *path* (e.g., starfish *spinning over* [the ball], starfish *spinning under* [the ball]; Pruden, Göksun, Roseberry, Hirsh-Pasek, Golinkoff, 2012). Importantly, these results were consistent even when the ground object was removed. Manner is how an individual figure moves; it is not about the relation between the figure and a ground.

How does language influence infants' concepts of path and manner? To test whether language would facilitate category formation at an earlier age, Pruden et al. (2013) provided a linguistic label (*javing*) as English-reared 7- to 9-month-old infants were familiarized with events in which the starfish performed the same path with four distinct manners. The

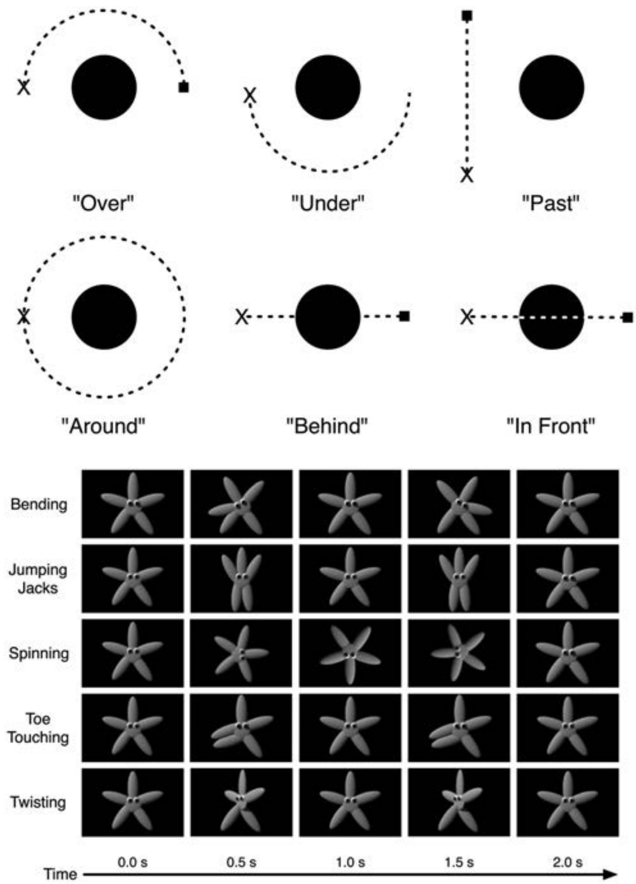

Figure 3.1 Paths and manners used in stimuli. Although illustrated as a series of static postures, the starfish performed the manners as continuous motions. With permission from John Wiley & Sons Ltd.

presence of a label promoted attention to the familiarization events *and* helped infants form a category of path—something that was not possible for 7- to 9-month-olds in the absence of a label. This finding is consistent with research showing that language facilitates the formation of object and spatial categories (Booth & Waxman, 2002; Casasola, 2005), perhaps because linguistic labels help young children appreciate underlying relational structures that indicate category membership (Christie & Gentner, 2012).

Cross-linguistic investigations found that 14- to 17-month-old English- and Spanish-learning infants were equally likely to notice path and manner changes in a nonlinguistic event involving a starfish figure moving with respect to a stationary ball, even though these languages differ in the way they express manner and path linguistically (Pulverman et al., 2003; Pulverman, Golinkoff, Hirsh-Pasek, & Sootsman Buresh, 2008). However, when productive language ability was taken into account, subtle differences emerged. English-reared infants with larger vocabularies were more attentive to manner changes than to path changes. Similarly, Spanish-reared infants who had smaller vocabularies were more attentive to manner changes than path changes, whereas Spanish-reared infants with larger vocabularies did not attend more to any one element over the other. These cross-linguistic data suggest that focusing on event components that are likely to become encoded in one's native language (i.e., *manner* for English speakers; *path* for Spanish speakers) constrains the number of hypotheses that must be entertained for a word's referent and may facilitate word learning. For those children biased to focus on aspects of events that are not later conflated in the verb, attention to the "wrong" aspects might act as a hurdle for verb learning.

A parallel progression from global to language-specific strategies has been identified in Spanish-, English-, and Japanese-learning children (Maguire, Hirsh-Pasek, Golinkoff, Imai, Haryu, Vanegas, Okada, Pulverman, & Sanchez-Davis, 2010). Across languages, younger children (2- and 2.5-year-olds) were more likely to attach a novel verb to a figure's *path* rather than *manner*, but 3- and 5-year-olds displayed strategies that reflected their native language's specific patterns of verb use. Allocating attention to the components that are expressed in one's native language may support—as well as be the result of— language acquisition. Thus, the 3-year-old Spanish-learning child who attends to path changes will likely learn more path verbs, but the 3-year-old Spanish-learning child who inordinately attends to manner may be at a disadvantage since manner verbs are relatively infrequent in her language.

Figure and Ground

Like path and manner, figure and ground are perceptually accessible, universally encoded, and packaged differently across languages. In English, for example, prepositions such as *over*, *into*, and *across* tell us something about the path the *figure* follows and the spatial features of the *ground* object. Thus, "into" not only refers to the path that the figure traverses, but indicates that the ground object is a type of enclosure (Talmy, 2000). Critically, English rarely conflates information about the ground within the verb itself (although, consider *swim*, *ski*, and *fly*). In other languages such as Korean and Japanese, however, "ground verbs" routinely encode the spatial configuration of the ground being traversed (Muehleison & Imai, 1997). Japanese, for example, classifies motion path verbs into two categories: directional-path and ground-path verbs. Directional-path (DP) verbs define the direction of motion relative to a starting point or goal (e.g., *hairu* "enter," *iku* "go," *kaeru* "return," *kuru* "come"), and do not restrict the ground on which the motion occurs (Göksun, Hirsh-Pasek, Golinkoff, Imai, Konishi, & Okada, 2011; Muehleisen & Imai, 1997). However, ground-path (GP) verbs such as *wataru* "go across," *koeru* "go over," and *nukeru* "pass through," incorporate properties of the ground along with the direction of motion (Beavers, 2008; Muehleisen & Imai, 1997; Tsujimura, 2006).

According to the "trading spaces" hypothesis, all infants—regardless of the language they are learning—should show initial sensitivity, prior to the growth of their lexicons, to changes in both figure and ground; however, only Japanese children will *maintain* sensitivity to changes in ground-path that are encoded linguistically, whereas English-learning infants decrease their attention to this distinction that is not relevant for language. Göksun and colleagues (2011) tested English-learning infants' sensitivity to figure and ground (see also Bornstein, Arterberry, & Mash, 2010). They familiarized infants to a dynamic scene in which a figure crosses a ground (e.g., a woman crosses a street) and tested infants' discrimination of figure changes (e.g., a man crossing a street) and ground changes (e.g., the woman crossing a field or railroad track). Infants detected changes in the moving figure by 10–12 months and changes in ground by 13–15 months in dynamic events. Interestingly, English-learning infants showed sensitivity to subtle ground distinctions such as whether the ground extended in a line or a plane. Although this semantic component is not encoded in English, it is encoded differently in the Japanese verbs for crossing these grounds (e.g., *wataru* for crossing a bounded surface like a street vs. *tooru* for crossing an unbounded surface like a field; Muehleisen & Imai, 1997), suggesting that when language is just beginning to emerge, infants evince early sensitivity to event features that become encoded in *any* language—not just their own (Hespos & Spelke, 2004).

We also have evidence that infants' level of language development relates to whether they are sensitive to the Japanese ground-path distinctions in nonlinguistic events. Göksun et al. (2011) reported that both Japanese and American infants distinguished between Japanese grounds in nonlinguistic events at 14 months. However, by 19 months, while all the Japanese babies noticed ground-path distinctions, only the low vocabulary American babies noticed ground-path distinctions. Thus, in contrast to younger infants who are producing their first words, older children, who have a large and rapidly growing lexicon, make ground distinctions specific to the language they are learning. These findings on the perception and discrimination of nonlinguistic events support the argument that language influences the processing of event components.

Konishi, Golinkoff, and Hirsh-Pasek (2014) investigated this hypothesis by testing both 14- and 22-month-olds with videos of events in the two ground-path categories (*wataru* and *tooru*). As predicted, 14-month-olds distinguished between the ground-path categories when neutral language was used (i.e., Wow! What do you see? Check!), while the older group did not see these distinctions. Children in the younger group who were offered a single word to describe these events (i.e., She's walking *toke* the road), dropped discrimination between these event components. Conversely, when the older group was offered two unique words that mapped to the two unique types of events, their ability to discriminate between Japanese ground-path categories was resurrected.

Summary

Our foray into nonlinguistic constructs suggests that infants are well equipped to find units within dynamic events that will eventually be labeled by words in their vocabulary. Initially, they seem to be sensitive to all distinctions rather than merely those that will appear in their home language. In the case of figure and ground, this means that both Japanese- and English-reared babies behave like Japanese speakers (since Japanese encodes both distinctions in certain verbs). Moreover, infants—regardless of the language they are learning—attend to changes within these units and begin to construct categories that incorporate a number of perceptually distinct exemplars (e.g., over, under, behind, through) for a single construct (i.e., path) before their first birthdays or shortly thereafter. As infants are exposed to the language-specific ways in which the world is packaged by native speakers of their ambient language, they selectively attend to these distinctions over those that are not codified in their language. This developmental pattern loosely parallels the perceptual narrowing of infants' phonemic discrimination from all sounds that can occur across the world's languages to only those contrasts made in their native language (Werker & Tees, 1984). We can speculate that the fine-tuning of infants' attention to language-relevant constructs is related to subsequent language acquisition (Pulverman et al., 2003, 2008; Göksun et al., 2011; Maguire et al., 2010). Though evidence suggests a neurological basis to the perceptual narrowing observed in phonemic development (Dehaene-Lambertz & Baillet, 1998; Minagawa-Kawai, Mori, Naoi, & Kojima, 2007), a parallel finding to support the trading-spaces hypothesis awaits discovery.

How Infants Parse Events for Language: Possible Mechanisms

Thus far, we have investigated event components as isolated features of nonlinguistic units, such as path and manner. Events, however, are fluid combinations of units organized into larger meaningful sequences that allow us to represent the patterns of experience. Similar challenges that face the infant in segmenting the speech stream are also present as the infant segments the event stream. For example, even a relatively simple event such as "doing laundry" can be segmented into multiple units that are organized into *partonomic hierarchies*, reflecting the relation between parts and subparts (Zacks & Tversky, 2001). A single act of "doing laundry" can be construed as three units (e.g., *washing*, *drying*, and *folding*) or be subdivided further into every menial portion of the task (e.g., *reaching into the basket, moving clothes to the washing machine*, *adding detergent and fabric softener*, etc.). Just as infants must identify the patterns in fluid speech to extract words and phrases, they must also attend to the structure of events to segment the objects and actions and understand where one event ends and another begins. Although the mechanisms that support the process of event segmentation have been studied in adults (Newtson & Enquist, 1976; see Zacks & Tversky, 2001, for a review), we know very little about this process in infants. How do infants detect patterns in the swirl of activity around them?

Infant-Directed Action

One potential cue to event structure occurs within the adult-child dyad as adults modify their behavior in specific ways to highlight action boundaries. Evidence suggests that caregivers make modifications to their gestures during infant-directed action in ways that echo the verbal modifications observed during infant-directed speech. Adults' "motionese" (i.e., motion directed toward infants) has been compared to action directed to adults and is shown to involve more repetitions of actions, more exaggerated, expansive movements, and smaller, simpler action units rather than complex combinations of action units (Brand, Baldwin, & Ashburn, 2002; Brand, Shallcross, Sabatos, & Massie, 2007). Adults also use more eye gaze (i.e., both duration and frequency) during infant-directed relative to adult-directed action, and even adjust eye gaze to the developmental stage of the infant (i.e., longer but less frequent gazes for 6- to 8-month-olds relative to 11- to 13-month-olds; Brand et al., 2007). This infant-directed eye gaze specifically aligns with, and therefore highlights, event boundaries (Brand, Hollenbeck, & Kominsky, 2013).

What Goes Together? Audiovisual Cues to Event Boundaries

"Acoustic packaging" (Hirsh-Pasek & Golinkoff, 1996; Wrede, Schillingmann, & Rohlfing, 2013) describes adults' tendency to synchronously pair their linguistic utterances regarding particular action units with those action units when speaking with infants. For example, a mother exclaiming, "Let's change that diaper" before the event and, "Now we are all done!" at the event's conclusion may provide an additional cue to meaningful segments (e.g., changing a diaper) within a more complex event (e.g., getting dressed). This construct is supported by findings that adults temporally align their speech and action as they demonstrate actions to their 8- to 13-month-old infants (Meyer, Hard, Brand, McGarvey, & Baldwin, 2011). They also punctuate their actions with action-based utterances more frequently during interactions with infants than interactions with adults (Schillingmann, Wrede, & Rohlfing, 2009). Crucially, infants may capitalize on this temporal synchrony to detect well-formed compared to ill-formed action units by 9.5 months (Brand & Tapscott, 2007; Gogate & Hollich, 2010, 2013). Thus, it appears that infants use multimodal synchrony in the ambient language as a cue to event boundaries, even before they understand what that language represents.

Although there is no direct evidence that acoustic packaging supports infants' ability to learn words for the observed action (e.g., verbs), evidence for how infants learn object labels (e.g., nouns) supports such a prediction. For example, 8-month-old infants are more

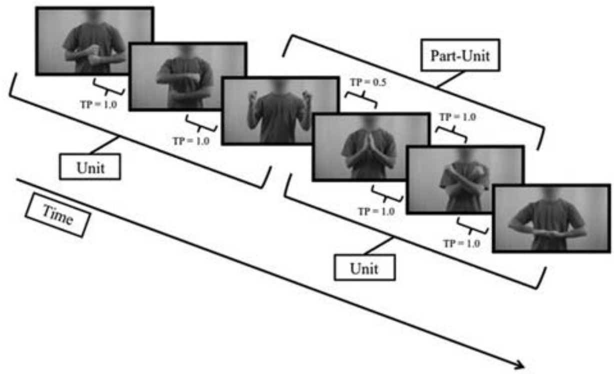

Figure 3.2 Examples of units and part-units. Each unit comprised three hand motions that always appeared together in the same order. Part-units combined the third hand motion from one triad with the first two hand motions from a different triad. Each pair of successive hand motions within a unit had a transitional probability (TP) of 1.0; the transitional probabilities for the hand motions within a part-unit were .5 for the first pair and 1.0 for the second pair. With permission from John Wiley & Sons Ltd.

likely to learn the link between syllables and objects when the object is moved in synchrony (rather than out of synchrony) with the syllable (Gogate, Bahrick, & Watson, 2000; Gogate, Bolzani, & Betancourt, 2006).

Tracking Statistical Regularities in Event Structure

Infants' ability to track statistical probability in auditory speech is well documented (Aslin, Saffran, & Newport, 1998; Estes, Evans, Alibali, & Saffran, 2007; Romberg & Saffran, 2010; Saffran et al., 1996). New evidence suggests that infants also use a statistical learning mechanism to parse continuous, dynamic events and that this process may work in concert with other cues that scaffold attention to event structure. By 8 months, infants are sensitive to the sequential statistics of actions performed by a human agent (Roseberry, Richie, Hirsh-Pasek, Golinkoff, & Shipley, 2011). Infants observed a sequence of hand motions in which certain motions (e.g., arms aligned in parallel) reliably followed others (e.g., stacking both fists) to form units that combined into longer sequences, yielding transitional probabilities between the units of 1.0. Part-units consisted of the last hand motion of the preceding unit and the first two hand motions of the following unit (Figure 3.2), yielding transitional probabilities of 0.5. Paralleling work in the speech segmentation literature, looking times revealed differential processing of statistically intact units, that is, units that reliably followed one another compared to part-units.

Furthermore, additional research suggests that infants can segment actions based solely on sequential predictability, without the additional cue of transitional movements that physically constrain the upcoming hand motion (Stahl, Romberg, Roseberry, Golinkoff, & Hirsh-Pasek, 2014). This research eliminated all movement cues that connected one unit to the next by ensuring that the animated agent (a starfish with eyes) performed whole-body actions that started and ended in a fully extended "star" position (Figure 3.3; Stahl et al., 2014).

This ability may be important for a number of reasons. Bottom-up cues such as infant-directed action, statistical regularities, and acoustic packaging appear to be potent candidates for the figurative commas and periods that punctuate events. These mechanisms support *both* the deconstruction of complex events into meaningful units *and* the reassembly of these meaningful units into the predictable patterns and routines of human behavior. These mechanisms may provide a general tool for infants to break into events that then allow them to categorize actions, predict outcomes, and learn language.

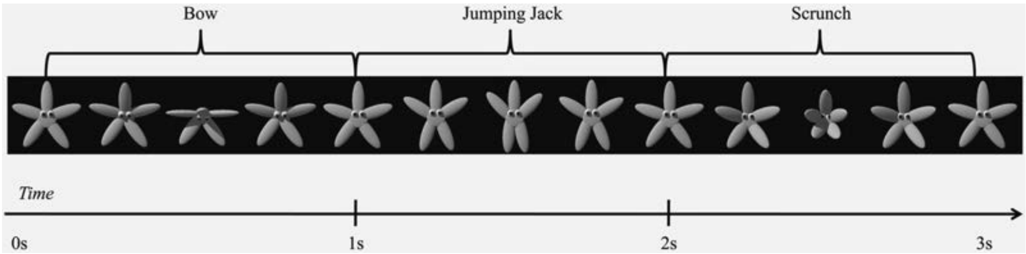

Figure 3.3 Sample sequence of actions from the familiarization corpus. These static images represent what was shown in the dynamic event. With permission from the Society for Research in Child Development, Inc.

Despite infants' limited experience in the world, they might also be sensitive to some robust top-down cues that could signal meaningful breaks in the action (Hespos, Grossman, & Saylor, 2010). One potential candidate for a top-down cue in infancy comes from particular attention to one of the event's components: the goal.

A Role for the Goal

Goals are highly salient (Krogh-Jespersen & Woodward, this volume). Two-day-old newborns orient more quickly and look longer to goal-directed compared with non-goal-directed actions (Craighero, Leo, Umilta, & Simion, 2011). Within the first year, infants are sensitive to goal changes following habituation to a simple motion event (Lakusta, Wagner, O'Hearn, & Landau, 2007) and can even *predict* with their gaze the goal of grasping actions (Kanakogi & Itakura, 2011). Infants may prioritize goals in their nonlinguistic representations of events because they consistently signify and sum up the intention of the actor and provide a structured template for more abstract linguistic representations that encode the agents' intentions. Thus, the monkeys "grooming" may have little perceptual similarity to a cat's "grooming" behaviors, but they nonetheless fit into the same verb category because the animals' intentions are similar.

Using a paradigm originated in the speech segmentation literature (Hirsh-Pasek et al., 1987), researchers have explored whether there are differential effects on visual orienting and neural activity when artificial pauses are inserted into categorically distinct moments of continuous events. A well known behavioral experiment tested whether, following habituation to a continuous 4-second event (e.g., "hanging up a towel"), 10- to 11-month-olds would differentiate artificial pauses inserted in the middle of the action (e.g., reaching for the towel) and pauses placed at the action's conclusion (e.g., grasping the towel; Baldwin, Baird, Saylor, & Clark, 2001). Infants dishabituated when the pause interrupted the action, but not when the pause occurred at the action's completion. This suggests that when viewing the original event without the artificial pause, infants detected the action completion, but not the middle of the action, as an event boundary. In this way, infants may attend to action units that come to be categorized and labeled with words. This important finding leaves open the question of whether infants' dishabituation was due to their appreciation of goal-directed action or rather their familiarity with the everyday event of hanging up a towel.

To test whether children would detect similar boundaries in a relatively novel event comprised of three actions, this methodology was adapted to an event-related potential (ERP) paradigm (Pace, Carver, & Friend, 2013). Even though children had no *a priori* experience with the event, brain activity distinguished intact from disrupted units of action, suggesting that they were sensitive to the goal structure of an unfamiliar event. Pace, Levine, and colleagues (2014) similarly tested infants' sensitivity to goal categories in the unfamiliar, dynamic event of figure skating. Looking-time and ERP methodologies revealed that, similar to adults, 10–11-month-old infants discriminated goals from other parts of the event, including arbitrary moments within the action sequences and categorical sources of those sequences. Attention to the goal—in familiar and unfamiliar event contexts—may facilitate children's ability to detect relevant boundaries that will eventually be labeled by categories of verbs.

Summary

The evidence presented suggests that a number of nonlinguistic event constructs are discriminable to infants when presented in isolation. We also suggested that infants not only attend to isolated components of events that will eventually appear in language, but that they have both bottom-up (statistical learning, acoustic packaging) and top-down strategies (attention to goal-structure and actor intent) for breaking fluid event streams into bite-sized units and—perhaps—for re-assembling these units into predictable routines (e.g., doing the laundry) that are described linguistically. This growing body of literature suggests that within the first year, or shortly thereafter, infants have the conceptual foundations in place to begin to represent the *relations* between these event components that come to be labeled by nouns, verbs, and spatial prepositions. Success in language learning requires that infants tackle a tripartite process that includes parsing the speech stream, segmenting the event stream, and then conquering the problem of *indeterminacy of reference*. We have shown that babies are remarkably adept at the first two tasks and possess dynamic collections of word forms and event structures. How do infants make use of this information as they build their receptive vocabularies and begin to use words productively?

Recent Findings From the Language Front

Despite the availability of a rich combination of cues, infants' ability to use these cues in the service of language acquisition may follow a more protracted developmental trajectory. Under the Emergentist Coalition Model, children draw on attentional, social, and linguistic cues differentially over developmental time to break the language barrier (Hollich et al., 2000; see also Lavin, Hall, & Waxman, 2006). Our final section evaluates new empirical data on language acquisition using the model as a framework, focusing squarely on the mapping problem. Importantly, our focus has shifted from *what* processes underlie language acquisition to *how* the processes underlying word learning change across development.

Baby's First Words

Language comprehension precedes and exceeds production throughout the early years of development (Fenson et al., 1994; Hirsh-Pasek & Golinkoff, 1996; O'Grady, Archibald, & Aronoff, 2010). Experimental studies using the classic head-turn preference procedure and the Intermodal Preferential Looking paradigm (Golinkoff, Hirsh-Pasek, Gordon, & Cauley, 1987; Hirsh-Pasek & Golinkoff, 1996) revealed that one of the first words infants differentially respond to is their own name. By 4.5 months of age, infants are attuned to the sound pattern of their own name (Mandel, Jusczyk, & Pisoni, 1995), suggesting that input frequency plays a role in word learning. Just six weeks later, they can pick their name out of fluent speech and recognize new words that follow it or Mommy or Momma (Bortfeld et al., 2005). They can also identify the referents of frequent words like "Mommy" (Tincoff & Jusczyk, 1999) and common nouns for food and body parts (Bergelson & Swingley, 2012; Tincoff & Jusczyk, 2012). Moreover, infants attach these labels to object *categories* since each trial contained a different instantiation of the target word (e.g., a different banana) paired with a slightly varied label produced "live" by the parent, mimicking the type of linguistic and nonlinguistic generalization required.

Using the same procedure, Bergelson and Swingley (2013) tested whether infants understood relational terms—words such as *all gone*, *hug*, or *dance*. Convincing comprehension of these words was not robustly demonstrated until 14 months of age (Bergelson & Swingley, 2013). This developmental progression is consistent with accounts that emphasize the important role that perceptual factors—such as the word's *shape*, *individuability*, *concreteness*, and/or *imageability*—play in early word learning (e.g., Gentner, 1982; Gentner & Boroditsky, 2001; Landau et al., 1988; Ma, Golinkoff, Hirsh-Pasek, McDonough, & Tardiff, 2009; Maguire, Hirsh-Pasek, & Golinkoff, 2006; McDonough, Song, Hirsh-Pasek, Golinkoff, & Lannon, 2011).

Perceptual Saliency Guides Early Word Learning

If one of the first strategies used by infants acquiring language is to preferentially attend to referents that are highly perceptually salient, then words that map to perceptually salient objects or actions should appear first. This hypothesis has been empirically confirmed. As early as 6 to 8 months, infants link objects and labels when mothers use perceptually salient movements (e.g., shaking or looming motions) to teach their infants a novel word (Matatyaho & Gogate, 2008), likely because these gestures bring the object to the foreground of the child's attention (Matatyaho & Gogate, 2008; Matatyaho-Bullaro, Gogate, Mason, Cadavid, & Abdel-Mottaleb, 2014). A recent study found that when a novel object was illuminated from below with a light—effectively increasing the saliency and drawing attention to the target—2-year-olds were more likely to retain the novel label than when it was not illuminated, or when pointing was used to draw attention (Axelsson, Churchley, & Horst, 2012). Thus, perceptual cues that make objects salient, either cues inherent to the object or outside the object, help infants converge on the correct word referent.

When perceptual and social cues are put into competition, infants respond differentially based on their word learning experience. Infants saw two objects, one interesting (e.g., brightly colored) and one boring (e.g., colorless and motionless) while a speaker positioned between the objects labeled either the interesting or boring object. The speaker also used social cues like eye gaze and sometimes handling to indicate which object was being labeled. When the interesting object was labeled (the *coincident* condition), perceptual and social cues converge. However, when the boring object is labeled (the *conflict* condition), children must override their natural preference for the interesting (perceptually salient) object to map the label correctly—that is, children must weight social cues over perceptual ones (Houston-Price, Plunkett, & Duffy, 2006; Pruden et al., 2006). While 10-month-olds associate the novel word with the interesting object regardless of condition, 12-month-olds do not; they successfully learn the correct target in the coincident condition, but fail to form any mapping in the conflict condition (Hollich et al., 2000). By 19 months, infants were still attracted to the perceptually salient object, but could use social cues to learn the name for the boring object; only by 24 months could children convincingly override their preference for the perceptually salient object to learn the names for both the boring and interesting object (Hollich et al., 2000). These results suggest that perceptual saliency is a strong cue for word learning at first, and implicate a gradual shift in the weighting of social cues with respect to perceptual ones (Hollich et al., 2000).

Social Cues Gain Traction for Word Learning

In addition to perceptual cues to word reference, children have access to a rich tapestry of cues that make up the social fabric of their experience. Despite the social scaffolds provided by caregivers, language heard by infants tends to be incomplete and referentially ambiguous. As noted by Gleitman (1990), parents don't reliably say "block" exclusively in the presence of blocks. In addition, understanding the nature of a communicative exchange requires the interlocutors to access a number of social-pragmatic cues that cannot be gleaned from the semantic content alone. For example, an infant may hear her mother say, "I'm chilly," to which her grandmother replies, "I'll put the kettle on." Understanding the flow of conversational exchange depends on inferring the unstated meaning that making a cup of tea is a logical solution to being cold.

Infants are sensitive to a number of nonlinguistic cues that are an undeniably powerful source of information for language learning (Caza & Knott, 2012; Nelson, 2007; Tomasello, 2008) including eye gaze (Bloom, 2000; Booth et al., 2008; Brooks & Meltzoff, 2008), joint and triadic attention (Adamson, Bakeman, Deckner, & Romski, 2009; Baldwin, 1995; Carpenter, Nagell, & Tomasello, 1998), and goals and intentions (Baldwin et al., 2001; Buresh & Woodward, 2007; Carpenter, Akhtar, & Tomasello, 1998; Carpenter, Call, & Tomasello, 2005; Csibra, Bíró, Koós, & Gergely, 2003; see also Krogh-Jespersen & Woodward, this volume).

Despite early attention to social cues for object name learning (Baldwin, 1993; Brooks & Meltzoff, 2005), overcoming perceptual salience during *verb* learning appears to emerge gradually over the second year of life (Brandone, Pence, Golinkoff, & Hirsh-Pasek, 2007). Thirty-two 22-month-olds were taught a label for one of two available actions. Either the labeled or the unlabeled action produced a result (e.g., a light or a sound). At test, infants saw a video depicting the labeled action on one side of a split screen, and the unlabeled action on the other side. Results of a looking-time analysis revealed that 22-month-olds could only learn a word for an action when the speaker was naming the action *and* the action produced a result. When the speaker named an action that did not produce a result, children disregarded the social cues to reference and failed to learn a word. A second study revealed that 22-month-olds could not learn the label for an action when both possible actions had equally salient results. Finally, 34-month-olds in a third study managed to overcome the lure of a perceptually salient result and follow speaker cues to attach a word to the action that was less perceptually salient (Brandone et al., 2007).

One remaining question is whether infants' ability to access social and pragmatic sources of information for language lies in their sensitivity to physical properties inherent in subtle social cues (e.g., attention to eye gaze/saccades, facial expression, pointing, body motion) or in the appreciation of what these cues to behavior *imply* about the underlying motivations of the actor (Csibra & Gergely, 1998; Gergely & Csibra, 2003). Research on special populations is informative, as these children are characterized in part by impaired social functioning (Adamson Bakeman, Deckner, & Romski, 2009; Baron-Cohen, 1995). Parish-Morris and colleagues (2007) investigated how children with autism disorders (AD) and typically developing (TD) children used attentional (e.g., eye gaze) and intentional (e.g., what the speaker means to convey) cues during word learning. Both AD and TD children attended to eye gaze during word learning, but AD children only learned the labels for novel objects when they were perceptually salient or had predictable outcomes. That is, they did not identify the correct referent when the speaker's object-related actions were intended but unfulfilled. These findings suggest that eye-gaze alone was not sufficient for children with AD to glean communicative intention.

As TD children learn more about evaluating whether the speaker is reliable or trustworthy, their reliance on social information becomes even more sophisticated (for a review, see

Koenig & Harris, 2007). Nurmsoo and Bloom (2008) found that 3- to 4-year-olds rely on eye gaze as a cue to word reference *only when it is relevant* to the context as a whole; otherwise they rely on linguistic information (Nurmsoo & Bloom, 2008). Similarly, children ignore information about word reference when it is presented by an ignorant speaker, but learn a word from a knowledgeable speaker (Birch, Vauthier, & Bloom, 2008; Sabbagh & Baldwin, 2001; Sabbagh, Wdowiak, & Ottaway, 2003; Scofield & Behrend, 2008). By the preschool years, children flexibly and wisely exploit a wealth of pragmatic cues.

But we are getting ahead of the story. Infants' language learning hinges upon sensitive and responsive adults (Tamis-LeMonda et al., 2014). A recent finding suggests that the quality of the communication foundation established between parent and child at age 2 accounts for more variability in language outcome a year later than the amount of parent speech input (Hirsh-Pasek et al., 2015). Tamis-LeMonda and colleagues (2014) suggest that three specific features play an important role in word learning: temporal contiguity, contingency, and meaningful semantic content. This may be why infants and young children under the age of three are typically unable to learn words from television or video (Kuhl, Tsao, & Liu, 2003; Roseberry, Hirsh-Pasek, Parish-Morris, & Golinkoff, 2009; Zimmerman, Christakis, & Meltzoff, 2007). Indeed, when contingency is disrupted by frequent interruptions on mobile devices, word learning suffers. Reed, Hirsh-Pasek, and Golinkoff (in preparation) revealed that when mothers were interrupted by a cell phone call as they attempted to teach their 2-year-olds a novel verb, children were significantly less likely to learn the new verb than when parents were not interrupted. In a live video-chat format (e.g., Skype), however, 2-year-olds did learn novel verbs. Maintaining temporally contiguous, meaningful, and contingent responses enables word learning—even remotely (Roseberry, Hirsh-Pasek & Golinkoff, 2014).

Taken together, these studies demonstrate that infants gradually lend more value to social cues during word learning, and that they become increasingly discerning about when these cues provide reliable and valid information for language acquisition. Though the so-called "naming explosion" or "word spurt" is often dismissed as myth (Bloom, 2000), it is possible that the perceived acceleration in children's word acquisition around 18–24 months reflects infants' emerging ability to understand and recruit others' social cues for word learning. It is important to emphasize that cues to word meaning are rarely presented in isolation; rather, they frequently overlap to result in conflicting or converging sources of information. As Hollich and colleagues note (2000), "differential weightings do not imply weightings of zero" (p. 103). That is, even very young infants pay some attention to social eye gaze and even toddlers can be fooled by perceptual saliency. With development and experience, we see changes in the strategies employed by the budding word learner.

From Social Sophisticate to Loquacious Linguist: Breaking into Grammar

Grammar allows language-users to create complex phrases and sentences out of individual lexical units (i.e., words). In the second year of life, infants progress beyond one-word utterances (e.g., "baby") known as "telegraphic speech" and begin to combine words to express relations between referents (e.g., "Daddy feeds baby"; Brown, 1973). At what point in development do infants attend to grammatical cues to meaning such as word order, morphology (e.g., *-ing*, plural *-s*), or syntactic structure? And critically, is there evidence that children gradually assign more heft to linguistic cues when they come in conflict with other cues to word meaning?

Sensitivity to word order comes early, even before infants say a single word. Imagine two dynamic scenes: In one, Big Bird is tickling Cookie Monster; in the other, Cookie Monster is tickling Big Bird. Toddlers (mean age = 17.5 months) were asked to look at where Cookie Monster was tickling Big Bird. Toddlers used word order information to correctly infer which scene was the "correct" scene that matched the sentence. Infants used an abstract grammatical rule (SVO order in English) to determine which character was the subject (or agent) and which was the object (or patient) of a transitive action (Hirsh-Pasek & Golinkoff, 1996; Gertner, Fisher, & Eisengart, 2006; see also Dittmar, Abbot-Smith, Lieven, & Tomasello, 2008; Fisher, 2002).

Seidl, Hollich, and Jusczyk (2003) demonstrated that even 15-month-olds show some understanding of Wh-questions. Using the preferential looking paradigm, Seidl et al. showed infants scenes of familiar objects knocking into one another. The test question was formed as either a subject-question (e.g., *What hit the X?*) or an object-question (e.g., *What did the X hit?*). Comprehension of subject questions occurred by 15 months; 20-month-olds looked correctly to both subject and object questions. Infants are able to understand syntactic structure much earlier than suspected (Seidl et al., 2003).

Early syntactic knowledge, however, is still error-prone. By 19 months, children use the number of nouns in a sentence—distinct from the number of persons present in the scene—to help identify which event is correct (Yuan, Fisher, & Snedeker, 2012), yet they mistakenly assign different interpretations to "The boy and the girl are gorping" and "The girl and the boy are gorping" at 21 months (Gertner & Fisher, 2012). By 25 months children can interpret intransitive sentences with conjoined subjects correctly (e.g., "The bunny and the duck are *blicking*!"; Naigles, 1990), but without multiple morphological clues that the new verb is intransitive, even 28-month-olds can be fooled by a mismatch between number of argument positions and number of nouns in a sentence (e.g., "Find Big Bird and Cookie Monster *gorping*!"; Hirsh-Pasek & Golinkoff, 1996).

Together, these findings suggest that children begin to rely on a number of grammatical cues for language acquisition. The preferential looking method has been a boon to the field by allowing researchers to understand the trajectory of children's ability to exploit sentence structure in the service of language learning (Golinkoff, Ma, Song, & Hirsh-Pasek, 2013). In a more naturalistic context, however, children are not presented simultaneously with two videos side-by-side to help them constrain their interpretations. Can infants use syntactic cues to language learning even without a single visible scene?

Arunachalam and colleagues (Arunachalam, Escovar, Hansen, & Waxman, 2013) note that 60% of the verbs that mothers present in conversations with their children refer to events that are not currently observable. Their findings suggest that by 21 months, children can establish a representation of a novel verb's meaning even in the absence of a relevant visual scene and retrieve this information when a candidate causative referent comes into view (Arunachalam et al., 2013; see Yuan & Fisher, 2009, for similar findings at 27 months).

Additional research has begun to explore how syntactic cues work in concert to support language acquisition in general, and verb learning in particular. For example, a recent study manipulated the syntactic frame and the semantic content provided to 2-year-olds as they observed a man performing an action with a balloon that was labeled with a novel verb (e.g., "pilking"; Arunachalam & Waxman, 2014). Children learned the novel verb only when presented with rich semantic information that was packaged clearly in a single sentence denoting "who did what to whom." When a prosodic cue was required to correctly interpret verb meaning (as in French right-dislocated sentences, "He_i's great, Tom_i") 28-month-old French-speaking children defaulted to their knowledge of canonical sentence structure and did not learn the verb (Dautriche et al. 2014). By 3, however, children could integrate multiple cues to inform verb meaning, assigning more weight to the linguistic context than a misleading social cue (Nappa et al., 2009).

It has been established that toddlers use both syntactic structure and intentional inference to map novel verbs to discrete actions. Less is known about how toddlers map novel verbs to actions within the context of an ongoing event. To test this, a recent study created a continuous event sequence comprised of three relatively novel actions (Friend & Pace, 2011). A single action, embedded within the continuous event, was specified as the referent for a novel verb through a hierarchy of cues. One group of children heard the verb label ("Glorping!") at the onset and completion of the target action. Another group received intentional cues only (e.g., eye gaze and vocal intention, "Look!") without hearing the verb label during training—similar to Akhtar and Tomasello's (1996) "non-ostensive" context in which children learned words for an absent object or action. A third group received all three cues: eye gaze, vocal intention, and the verb label to demarcate the target action. Who learned the verb? Only children in the third condition, who received a rich combination of cues to verb reference, correctly identified the target action. Thus, learning a new word for an action (or even a noun, Booth et al., 2008) that is embedded within a continuous stream of activity may require a confluence of cues to verb meaning (Friend & Pace, 2011).

Summary

The data—classic and contemporary—speak to the predictions made by the ECM. Beginning as associationists, children gradually begin to *attend* to social cues and then to *recruit* a speaker's social cues to learn words for objects and actions; with experience, children learn that social cues such as eye gaze are not 100% reliable and begin to place more credence in linguistic cues to meaning. Within the first two years of life, there exists a remarkable progression from perceptually guided word learning to language acquisition in contexts that require children to evaluate the reliability of multiple cues simultaneously.

FUTURE DIRECTIONS

We began with a review of infants' remarkable abilities to detect, discriminate and categorize phonemes, track statistical patterns within speech input, and capitalize on features of infant directed speech. We reconsidered the mapping problem from an emergent framework (the Emergent Coalition Model; Hollich et al., 2000) that describes infants' ability to flexibly change the weighting of multiple factors in their quest to learn language. Investigating the infant's prowess in the perceptual, social, and linguistic arenas *independently* provides an important—but rather piecemeal—depiction of language development. Considered *together*, this evidence paints a holistic picture, revealing several emerging themes and pointing to exciting directions for future research. The next wave of research must test hybrid models longitudinally to tease apart children's progressive reweighting of different cues to word meaning. Specifically, it will be crucial to experimentally manipulate cues from the attentional, social, and linguistic realms to understand how children evaluate the relative importance of available cues, identify some as more informative than others, and integrate the useful sources of information to become proficient in their language.

Surely the language learning process is *dynamic* in that it evolves with age and experience, and *multifaceted* in that it cannot be reduced to a single mechanism. Future research must embrace this complexity if we are to make further inroads to understanding language development. Innovative research programs using head-mounted cameras to track infants' experience at a micro-level (James, Jones, Swain, Pereira, & Smith, 2014; Smith, Yu, Yoshida, & Fausey, 2015) as well as multidimentional models that consider the joint influence of factors at many scales (e.g., PRIMIR, Processing Rich Information from Multidimentional Interactive Representations; Werker & Curtin, 2005) are currently making headway in this arena. Research capitalizing on advances in imaging technology such as fMRI, MEG, and NIRS will help to identify the neural bases of language acquisition that validate developmental models.

Celebrating complexity will require a concerted effort to include children from diverse socioeconomic backgrounds (Fernald, Marchman, & Weisleder, 2013; Rowe, 2012) as well as language-impaired populations (Rice, 2013). It will also require further work with children learning more than one language (e.g., Konishi, Kanero, Freeman, Golinkoff, & Hirsh-Pasek, 2014; McCabe et al., 2013) and children learning a language other than English at home (Hoff, Core, Place, Rumiche, Señor, & Parra, 2012). The number of children who come from non-English-speaking homes was nearly 11.2 million in 2009, a rise from 4.7 million in 1980 (Aud et al., 2011) and by 2030, a majority of children will come from racial-ethnic minority groups (Hernandez, Denton, & Macartney, 2009). Thus, future investigations should consider language development within the microsystem encompassing individual differences in early exposure as well as the macrosystem composed of cultural values and customs.

Finally, we might also take a moment to reflect on our predecessors' contributions to the same questions that perplex us today. Revisiting, for example, Bloom and Lahey's (1978) original interactive model that considers the joint influence of content, form, and meaning or Werner and Kaplan's (1963) developmentally dynamic notion of "symbol formation" that emerges from the increasing differentiation *and* progressive integration of the infant's relationship with persons and objects, for clues to where we have been, where we are now, and where we need to go.

CONCLUSION

Returning to our opening vignette at the zoo, we fully appreciate the vastness of the task facing the infant. Language acquisition is a multipronged process that relies on linguistic and nonlinguistic inputs, as well as the infant's active contribution to organize the structure of experience. Revisiting this classic puzzle from novel perspectives and with innovative methodologies in our tool belts, we can appreciate the incredible sophistication that infants bring to the task of understanding and communicating about the events in their world. Only by uncovering infants' remarkable abilities in the perceptual, social, and linguistic arenas and evaluating how these abilities interact throughout the course of language development can we account for the pattern of change as language transforms into a vehicle for the infant to express increasingly complex thoughts and ideas.

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