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Trends and Transitions in Language Development: Looking for the Missing Piece

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In this article, we show that developmental neuropsychology can make significant inroads into the study of language acquisition. The 1st section describes new methodological developments in the field of language acquisition, including the headturn preference procedure (e.g., Fernald, 1985; Hirsh-Pasek et al., 1987) and the intermodal preferential looking paradigm (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Hirsh-Pasek & Golinkoff, 1996a). The 2nd section shows how these new methods are altering our view of the process of acquisition and placing more emphasis on the period prior to the emergence of speech. The 3rd section presents a profile of language acquisition, reviewing recent research in the areas of phonological, lexical, and syntactic development. Using Hirsh-Pasek and Golinkoff's (1996a) coalition model as a base, we examine major transitions in the landscape of development. Finally, we conclude that the transitions observed in the behavioral data offer ripe opportunities for the use of convergent neuropsychological data.

In his classic children's book, *The Missing Piece,* Shel Silverstein (1976) introduced a character formed from an incomplete circle. In a desperate search, the character is looking for his missing piece in the hopes of finding happiness and a better

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understanding of himself. To researchers in the area of language development, the research capability available in developmental neuropsychology may provide the missing piece. Scientists, educators, and reporters alike want to know how the brain develops and how input in the form of language stimulation affects the brain and promotes language learning. To date, however, there are only incomplete responses to these questions. We are told that there is a dramatic increase in neural density in the first 2 years of life and that this increase seems to reach its peak around the time when children enter the vocabulary spurt and launch into grammar (Elman et al., 1996). We are also told that input (linguistic and nonlinguistic) acts as a kind of sculptor to refine brain connections that are excited from without and within (Elman et al., 1996). However, we cannot yet give many specifics on the relation between brain growth and particular language advances. Just as Chomsky (1964) once thought that language development could provide a window into the mind, a better understanding of recent trends in language acquisition will allow language to become a window into the brain. By reviewing recent trends and transitions observed in the behavioral study of language, we offer new clues as to where to look for the missing pieces in the brain–language connection.

To that end, this article is organized in four parts. The first part reviews trends in the creation of research methodology. In the past 10 years, researchers who study language acquisition have developed several methods that permit a view of language acquisition from its inception. The second part demonstrates how these methods led to a different focus in the study of early language, from a focus on 2- and 3-year-olds learning grammar to a focus on infants who are analyzing speech and comprehending words and grammar in the first 2 years of life. The third part presents a profile of language development that takes these new trends into account. Using Hirsh-Pasek and Golinkoff's (1996a) coalition model as a base, major transitions on the landscape of development are examined in the acquisition of phonology, semantics, and grammar from infancy to age 3. Finally, the last part concludes by suggesting that transitions observed in the behavioral data offer ripe opportunities for the discovery of convergent data in neuropsychological research.

TRENDS IN THE DEVELOPMENT OF METHODS TO STUDY LANGUAGE ACQUISITION

To appreciate the way in which trends in methodology have transformed the field, we begin with a piece of ancient history. In 1970—almost 30 years ago—researchers struggled over what utterances such as "Mommy sock" meant (Bloom, 1970). Were children just conjoining two words without any underlying structure or were they expressing meaning relations such as *agent–object* (e.g., "Mommy [agent] put on my sock [object]")? Were they also expressing grammatical relations such as *subject* of the sentence (e.g., Mommy) and *object* of the sentence (e.g., sock)? At the time, the field could have profited from converging neuropsychological evidence to adjudicate between these claims. Such methods, however, were not yet on the scene. Much ink was spilled, and the issue is still largely unresolved. The issue became a matter of interpretation from one kind of data, data from language production. Chomsky (1964) himself exhorted us to develop methods that would "trick" children into showing what they know about language. He wrote:

> If anything far-reaching and real is to be discovered about the actual grammar of the child, then rather devious kinds of observations of his performance, his abilities, and his comprehension will have to be obtained, so that a variety of evidence may be brought to bear on the attempt to determine what is in fact his underlying linguistic competence at each stage of development. (p. 36)

In the 1970s, the field did not have many methods that allowed us to probe beyond what we could see in language production other than pointing at pictures (Fraser, Bellugi, & Brown, 1963) and acting out sentences on command (see Shipley, Smith, & Gleitman, 1969). These techniques, however, only allowed us to test children who would agree to play the game by the experimenter's rules and who already understood much language. If researchers wanted to study the very origins of infants' appreciation of the sound system of their language, how they learned words, and how they broke into the grammatical system, they needed to invent reliable methods that could be used before language production began.

In the late 1980s and now in the 1990s, there has been a striking increase in the number of techniques that researchers can use to understand what children know about language before they can produce it. Data resulting from these methods have had a dramatic effect on how we view the process of language acquisition, on where we see the significant transitions in language acquisition as occurring, and on the theories posited to account for the phenomenon. Indeed, there are enough new methods to warrant an edited book just on current methodological techniques within the field (McDaniel, McKee, & Cairns, 1996).

A number of labs around the country, for example, now use the headturn preference procedure, first introduced by Fernald (1985) and modified by Hirsh-Pasek et al. (1987). This method allows us to study young children's phonological and grammatical knowledge. In the headturn preference procedure (as seen in Figure 1), the child is trained that some linguistic or auditory stimulus emanates from the left and right sides of the apparatus when the red light on that side blinks. In some experiments, children are preexposed to a list of stimuli or a paragraph. They are then offered the original stimulus or a stimulus that is constructed to vary from the original in specific ways. By way of example, the paradigm was used recently by Jusczyk and Aslin (1995) to demonstrate that 7-month-old babies prefer to listen to a paragraph that contains familiar words to which they have been preexposed more than to a paragraph that contains novel words. Furthermore, using this technique,

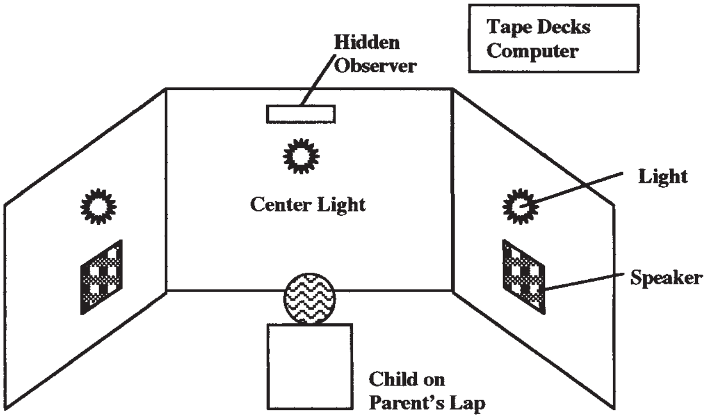

FIGURE 1 The headturn preference procedure.

Jusczyk and Aslin found that the effect went the other way as well. That is, 7-month-olds hearing a paragraph will then prefer to listen to a list of words from the paragraph more than a list of new words that did not appear in the paragraph.

Jusczyk and Aslin (1995) showed then that babies can remember the phonological and prosodic contours of words before they know anything about their meaning. This work as well as many other studies using this paradigm are reviewed in Jusczyk's (1997) definitive book on phonological development. The capabilities revealed in this book using the headturn preference procedure could be refined with neuropsychological data.

Golinkoff and Hirsh-Pasek's intermodal preferential looking paradigm (IPLP; Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Hirsh-Pasek & Golinkoff, 1996a, 1996b) has also greatly expanded our understanding of children's early language knowledge (see Figure 2). The key to this method is that it allows us find ways to investigate early language knowledge in children who cannot yet talk. The IPLP is a unique way to study language comprehension—both grammatical and lexical—and has recently been extended to study phonemic development (Hoskins, Golinkoff, Chung, Hirsh-Pasek, & Rocroi, 1998). In the IPLP, children are shown two simultaneous video events as they hear a linguistic message delivered from a central speaker. In the simplest case, a boat might appear on one screen while the other screen displays a shoe. A voice emanating from between the televisions asks the child, "Where's the shoe? Find the shoe!" The rationale of the method is that if children understand the language being used, they should watch the screen that matches the linguistic stimulus more than the screen that does not match it. To carry the example forward, they should watch the shoe more than the boat. Hirsh-Pasek and Golinkoff (1996a) described the method in detail as well as offering a new theory of language development. Neuropsychological data could only expand and enrich findings from the IPLP.

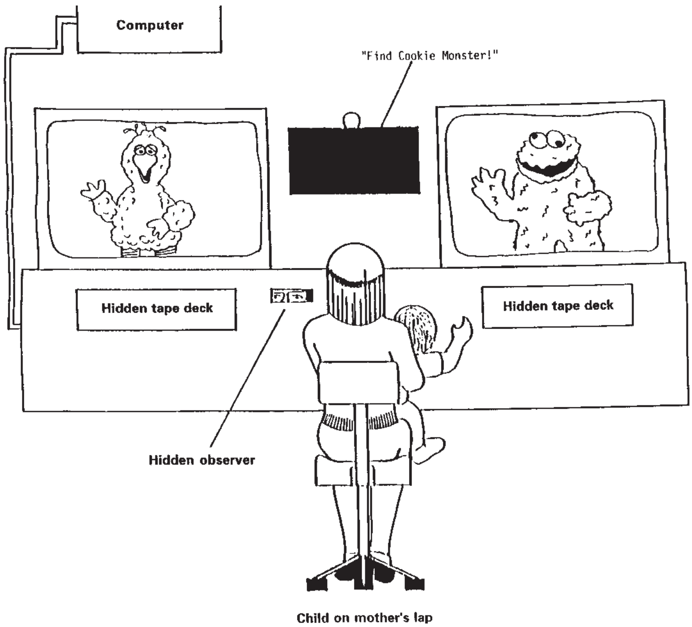

FIGURE 2 The intermodal preferential looking paradigm.

The IPLP has recently been extended into a new 3-D version (Golinkoff, Hirsh-Pasek, & Hollich, 1999; Hollich, Hirsh-Pasek, & Golinkoff, in press) that utilizes real objects instead of videotaped displays. As seen in Figure 3, this method incorporates the use of real objects that can be presented side by side on a board developed by Fagan (1971; Fagan, Singer, Montic, & Shepard, 1986) that flips. Using this method, we can teach babies the names of novel objects under a range of conditions. Then, as in the original IPLP, we can test for whether babies learned the name of the object by presenting two objects on the board and asking for one of them by name. If children learned the object name, they should look more to the matching than to the nonmatching object. The method has now been used with hundreds of babies between the ages of 12 and 24 months. The unusual thing about this method is that there is so little participant loss, even at the youngest ages.

A fourth method, the habituation paradigm, also uses visual fixation as the dependent variable and has been adapted to the study of linguistic questions. Gogate and Bahrick (1998) and Werker, Cohen, Lloyd, Casasola, and Stager (1998) recently developed a match–mismatch procedure that crosses linguistic and visual stimuli after habituation occurs. For example, Gogate and Bahrick habituated 7-month-olds to the presentation of a crab concurrent with the vowel sound /ah/ (as in *ma*) and a lambchop presented with the vowel sound /ee/ (as in *see*). If the baby learned the association, then changing the pairings, putting /ah/ with the lambchop and /ee/ with the crab, should instigate dishabituation. Interestingly, babies only

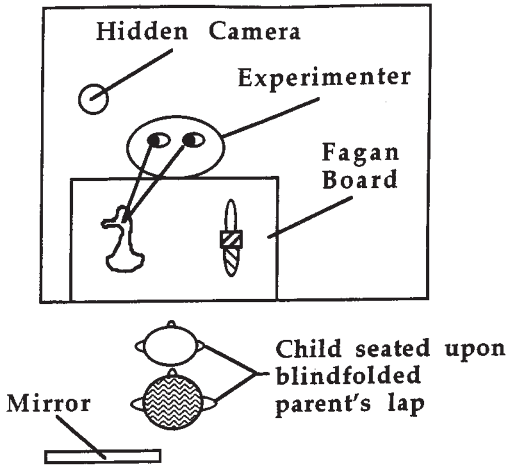

FIGURE 3 The 3-D intermodal preferential looking paradigm.

showed recovery from habituation, evidence of having learned the association, when the object moved synchronously with the production of the vowel sound. When the objects did not move or moved asynchronously, dishabituation did not occur. This method has also proven useful for the study of early phonological discrimination (Stager & Werker, 1997) and the processes involved in early word learning (Werker et al., 1998).

Finally, a method that we put into the same category as these other three methods is the use of neuropsychological measures such as cortical evoked response potentials (ERPs), whose products fill the pages of this and related journals and books (e.g., Molfese & Betz, 1988). These methods require only that the child sit reasonably still to avoid movement artifacts and pay attention to the stimulus presented. They, therefore, have tremendous advantages for tapping into the response of the brain to a wide range of stimuli while not requiring that the participant really do anything other than attend.

There are two important points to highlight about these new families of methods and how they have already advanced the field. First, these methods make it possible to study language development prior to, as well as after, the child's first single- or two-word utterance. This is crucial to our enterprise because these methods open up the course of development to our inspection. Second, all of these methods make minimal demands on infants and young children by asking that infants respond with capabilities already in their repertoire. These methods use dependent variables such as head turning, looking, and listening. None of these methods require that children follow commands (e.g., acting out commands) or talk to demonstrate their linguistic capabilities.

We predict that the wave of the future will be the use of multiple methods, both behavioral and neuropsychological, on the same research projects to better understand behavior through interlaboratory collaborations. In particular, neuropsychological data can be extremely useful in looking at a number of putative shifts that have been uncovered in the behavioral data and that now form the cornerstones of language development theory. Observing a corresponding and convergent shift in neuropsychological response data can help to solidify findings in our literature at large.

TRENDS IN THEORY

The research products of the methodological advances just reviewed have significantly altered the way in which the field views early language development. Language-learning infants of the 1970s came in two varieties. Either they were thought to be equipped with innate language-learning devices that sifted through an impoverished input to generate language or they were carefully molded by interactions in the environment that guided language growth through infant-directed speech and expansions and repetitions of child speech. Hirsh-Pasek and Golinkoff (1996a) referred to these families of theories as *inside-out* and *outside-in,* respectively. We contend that these views are more alike than they are different and that they share a host of common presuppositions. Nonetheless, these more extreme views are still well represented in the warring factions of the field of language acquisition. Recent findings in infant research have given way to a new kind of theory that some have defined as the *radical middle*. Led by Karmiloff-Smith (1992), the new brand of language development theories holds that infants are biased to attend to particular stimuli over others in the environment. This initial "jump start" primes the system so that children can then construct ever more complex behaviors in the course of development. The search for the initial biases then began. Infant researchers in phonology, semantics, and syntax began to hunt for the developmental primes for language learning. The infant language learner of the 1990s was to become a baby with initial biases who performed statistical and distributional analyses on the input and who constructed language out of somewhat meager beginnings. The new focus was on the very young language learner of 0 to 18 months and not on the more advanced language user in the "geriatric" set of 2 or 3 years.

Hirsh-Pasek and Golinkoff's (1996a) coalition framework of language development is in the spirit of these new models. As seen on Figure 4, the infant is surrounded by multiple inputs—prosodic, semantic, environmental, and so on—at all times. Within each input, children selectively attend to certain stimuli over others. Using what Hirsh-Pasek and Golinkoff called *guided distributional learning,* infants, like budding statisticians, use initial biases as the building blocks to create far more complex linguistic representations. One distinction between the coalition model and those like Karmiloff-Smith's (1992) is that, in the Hirsh-Pasek and Golinkoff framework, all input systems are not created equal. Rather, as in dynamic systems theory (Smith & Thelen, 1993), infants are differentially sensitive

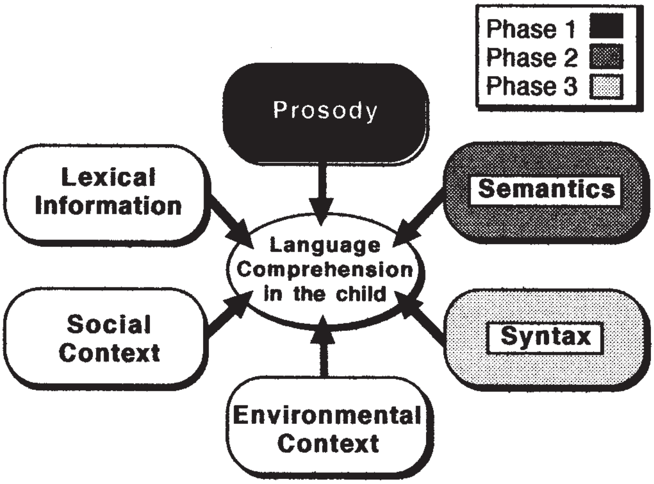

FIGURE 4 The three developmental phases in the coalition model of language comprehension.

to certain inputs over others during the course of development. Thus, at the earliest phase of language development, the prosodic aspects of the input is primary. Babies appear to notice that sentences begin and end with cues like vowel lengthening or pitch declination and that meaning has more to do with the melodies of speech (its prosodic contours) than with the words that are used (Fernald, 1989). Babies coo happily when parents use a happy voice to say, "You're ruining my life! I hate you!"

This period of reliance on the prosodic aspects of language is followed by a period of reliance on semantic input. Initially, semantic probability rules the day. Thus, for example, when presented with a picture of a baby and a mommy, children ignore the syntax in the sentence, "Where's the baby's mommy?" and interpret the sentence as if it meant "the mommy's baby," pointing to the baby instead of to the mommy (Golinkoff & Markessini, 1980). Finally, once children are around the age of 2, they come to be able to rely on syntax—not semantic probability—to interpret sentences describing improbable relations like "The mouse chases the elephant" (Strohner & Nelson, 1974).

It is in this theoretical framework that we describe some of the primes and transitions in phonology, semantics, and grammar that earmark good places to look for convergent data using the tools of neuroscience.

TRANSITIONS IN LANGUAGE DEVELOPMENT

Within the newer models, three questions become central. First, what are the developmental primes? That is, what are the biases with which children begin their language-learning journey? These can be conceived of as abilities, such as phoneme discrimination, that come for free at birth or as skills that babies construct at one level that then serve as primes for the next. Second, can children use the primes to do guided distributional analyses in the service of language learning? That is, can research uncover what in the input the child is computing to move to the next phase? Third, what are the marked transitions in development that take place within as well as between phases? Each of these questions is examined with respect to phonological, semantic, and syntactic development. Given the wealth of research in the area of infant language development, however, we can only review a sampling of the available research.

Prosody and Phonology

What are the developmental primes? Groundbreaking research at Brown University (Eimas, Siqueland, Jusczyk, & Vigorito, 1971) suggested that babies come into the world prepared to discriminate between phonemes in all languages (see Jusczyk, 1997; Werker & Pegg, 1992 for reviews). Eimas et al. further established that babies hear speech sounds in the same way that adults do, exhibiting what has been called *categorical perception*. That is, infants and adults tend to call a range of sounds /p/ and a range of different sounds /b/. Indeed, even though we can experimentally create an artificial situation such that a /p/ is acoustically closer to the typical /b/, adults and babies will still hear the sound as within the bounds of /p/.

These early phonological abilities, in and of themselves, give rise to a number of research questions that have been investigated behaviorally and with neuropsychological techniques. For example, data confirm that presentation of language sounds creates a response in the auditory cortex (Marantz et al., 1996) and that speech sounds are responded to differently in the brain than nonspeech sounds (e.g., Molfese, Freeman, & Palermo, 1975). Neuropsychological tasks also confirm that /b/s are treated differently than /p/s and that categorical perception is reflected in brain processing (Marantz et al., 1996). These findings become key when we examine some of the research bearing on the second question.

Can babies use the primes to conduct guided distributional analyses in service to language learning? From the behavioral data, the answer is clearly *yes*. The fact that babies are sensitive to sounds allows them to notice sequences of sounds they hear frequently. Mandel, Jusczyk, and Pisoni (1995) found by using the headturn preference procedure that babies seem to recognize their own name by 4 months of age. Because babies prefer their own name over different names that share syllable number and stress patterns, it appears that babies are remembering the sounds that compose their names. This result raises a host of tantalizing questions, and few researchers (other than Jusczyk and his colleagues) are probing word storage (or perhaps we should refer to it as *acoustic string* storage) in babies this young. Do babies show a unique brain response to their own names even prior to 4 months? Could researchers use babies' brain responses to their own name as a kind of baseline to see what other words babies can recognize? Neuropsychological data could provide one path of discovery.

Babies also begin to notice which sounds occur in their language and which do not. One study (Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993) asked whether babies could tell the difference between words in their own and another language. American, English-reared babies heard words from either English or Dutch. Dutch is the perfect foil language because the prosody of Dutch is similar to that of English. Therefore, if babies can tell the difference between Dutch and English words, they must be doing so based on the sound segments that made up the words. Some of the Dutch sounds are not permissible in English. For example, Dutch uses the /r/ sound very differently than the English /r/, sometimes having /r/ sound like a trill, sometimes like gargling, and sometimes like gathering phlegm in the throat. Also, Dutch allows words to start with sound sequences like /kn/ and /zw/, and English does not. At what age might babies be sensitive to such differences? How many months of exposure to their native language is necessary to be able to learn about patterns of sounds that co-occur in the language stream?

By 9 months of age, American and Dutch babies could already distinguish between English and Dutch. At 6 months of age, babies showed no preference for words from their native language. These are impressive capabilities. Recall that the average 9-month-old is babbling and producing no words. Yet somewhere between 6 and 9 months of age, babies, like little statisticians, are computing which sounds occur in their language and which do not. Convergent neuropsychological data beg to be collected on when this shift in the ability to discriminate between native and nonnative sounds occurs.

However, there is an even more impressive finding. By 9 months, babies are sensitive to the sequences of sounds, or *phonotactics,* that are possible (or not possible) in their native language. Friederici and Wessels (1993) found that 9-month-old Dutch babies preferred to listen to syllables composed of phonotactic sequences that are legal rather than illegal in their own language. Furthermore, Jusczyk, Luce, and Charles-Luce (1994) showed that 9-month-olds are sensitive to the frequency of legal sequences in their own language, preferring to listen to phonotactic sequences that occur frequently in English over those that occur infrequently. Six-month-olds are not sensitive to these distinctions. Neuropsychological data could help converge on when and why this shift occurs.

Why are these findings about the capabilities of 9-month-olds important? Recognizing the sound combinations that can occur in their language gives babies a leg up in finding the breaks between the words. The 9-month-old baby has become a pattern detector who has an enormous advantage over the 6-month-old in finding words in the stream of speech. Thus, by the time babies are 9 months old, they are performing statistical analyses on the language they hear, noting which sound sequences can and cannot occur in their ambient language. This statistical knowledge gives them the ability to figure out that *prettybaby* must be two words, *pretty* and *baby,* and not three words, *pre, tyba,* and *by*. The sounds /tyba/ never occur together in English, and therefore must occur over a break between two words. By noting the possible sequences of sounds that can occur in their native language, infants are discovering where words begin and end. Are 9-month-old babies really this statistically sophisticated? Could an ability to calculate and remember the frequency with which they hear different sound patterns help them carve up the language stream? Positive answers to these questions were provided by another study by Saffran, Aslin, and Newport (1996).

In the headturn preference procedure, 8-month-olds listened for 2 min to a meaningless, continuous sequence of nonsense syllables said in a monotone. They were then given a chance to listen to new sequences of syllables, some of which conformed to the sequence of syllables possible from the original string and some of which did not. Would 8-month-olds prefer to hear new syllable sequences that preserved the probabilities they heard before or would they be just as content to listen to new trisyllabic "words" that did not conform to the statistical probabilities of the original string? Babies showed a preference for the strings that conformed to the probabilities of the original string. By 8 months, babies are sensitive to the statistical properties of the samples of speech they hear, even after only 2 min of exposure. Thus, guided distributional learning, building on the initial prime of phoneme sensitivity, assists the child in making finer discriminations in the stream of speech, discriminations that will lead to the detection of words.

This work begs for replication with neuropsychological measures. Indeed, if the research were expanded to test both children and adults, perhaps we would find that infant brains need less exposure to strings than adult brains to compute these probabilities!

The behavioral studies also address the third question: Are there any marked transitions in phonological development that are central to the course of language growth? The answer here is a definitive *yes*. In addition to the transitions already noted, there is also a fascinating transition that occurs between about 8 to 10 months of age when infants' sensitivity to the distinctions between nonnative phonemes begins to decline (Werker & Tees, 1984). By 10 months, for example, Japanese-reared babies can no longer hear the difference between the sounds /r/ and /l/. To our knowledge there is only one study (Marantz et al., 1996)—one with adults—that has examined brain responses to phonemes that can be discriminated by babies but are not used in the native language. Adults' brain responses show that Japanese speakers class /l/ and /r/ together. So just as these distinctions are not available for conscious use, they are not discriminated by the brain either. Replications and extensions of this work with babies would be most provocative.

In short, when we examine the area of *segmental phonology,* or research on the sounds that comprise human language, there is no doubt that behavioral research could and should be bolstered by brain studies.

Words

Prosodic and phonological information are only the first layer that children encounter in the coalition model. Once they master the sounds and sound sequences of their language, those acoustic strings we call *words* begin to pop out. The primes for word learning are the phonological and prosodic sensitivities that the baby refined in the first 9 months of life. These allow them to segment the stream of speech and find the words. The primes may also be a set of word-learning principles or constraints (Golinkoff, Mervis, & Hirsh-Pasek, 1994; Markman, 1989; Merriman & Bowman, 1989; Waxman & Kosowski, 1990) with which children begin word learning and which they refine as they go along. Children do more than just find the words, however. They must discover the form class of each word. How do children ever find the words in the first place?

For theoretical guidance in the area, neuropsychological researchers will see a reprise of the very same issues that divide researchers in the area of grammatical development. Although the inside-out and outside-in theorists have different names, many of the same issues are debated. Once again, there are two camps that fall on either side of the great divide. In the one camp, the social–pragmatic theorists (analogous to the outside-in theorists) emphasize how young children become word-learning apprentices to the adults in their environments, being guided to learn new words in the context of everyday, culturally specific events (e.g., Nelson, 1996; Tomasello, in press). In the other camp are the constraints or principles theorists, analogous to the inside-out theorists (Golinkoff et al., 1994; Markman, 1989; Merriman & Bowman, 1989; Waxman & Kosowski, 1990). These theorists hold that children approach the word-learning task with some biases, presuppositions, or primes about how to interpret words. No matter of maternal guidance can help children understand, for example, that words tend to label whole objects. Golinkoff et al. (1994) proposed a midline position within this debate. We argue that the principles that guide word learning are not all in place at the start of language acquisition. Rather, these principles develop from an immature to a mature state and initially serve as the developmental primes that get word learning off the ground. Indeed, we posit that there is a coalition model for word learning analogous to the coalition model Hirsh-Pasek and Golinkoff (1996a) developed for language comprehension. That is, consonant with a dynamic systems view (Thelen & Smith, 1994) and as shown in Figure 5, there are multiple cues available for word learning in the child's environment. Children are differentially sensitive to certain of these cues over others in the course of developmental time. Thus, at different points in development, the child can only mine some of these cues and not others. These cues are the developmental primes of word learning. As they come online in the course of development, they change their weights. Figure 6 shows how the lexical principles Golinkoff et al. posited are organized into two tiers. The following discussion focuses only on how experiments using neuropsychological techniques might get at the first tier.

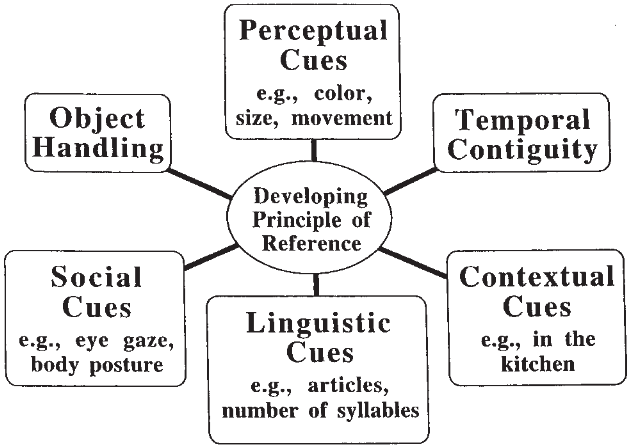

FIGURE 5 The coalition of cues available for word learning.

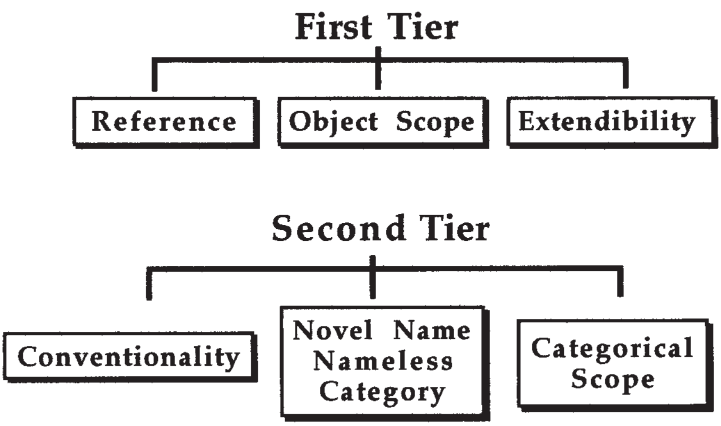

FIGURE 6 The two-tiered developmental lexical principles framework.

The most fundamental principle or prime for word learning (as Brown, 1958, noted) is the principle of *reference*. This principle states that words map to children's representations of objects, actions, and events. In Golinkoff et al.'s (1994) developmental lexical principles theory, reference starts out as an immature principle. At the start of word learning, words do not start out as symbols that stand for what they represent but are more like associates that go with what they represent. The difference is analogous to using the word *telephone* in the absence of the telephone to stand for the telephone versus associating the ring of the telephone with the instrument. Is there really a shift in the way early word meanings are represented in babies' brains? Could we find a way to ask whether the nature of the hookup between words and their meanings (cf. objects and their associated sounds) changes over the course of the 1st year of life? To study the origins of the principle of reference, we (Golinkoff, Hirsh-Pasek, & Hollich, 1999; Hollich, Hirsh-Pasek, & Golinkoff, in press) developed the 3-D IPLP described previously. In a series of experiments, we found that the cue of perceptual salience is extremely seductive for 12-month-olds. When presented with two objects, one boring and the other interesting, these babies will only learn the name of the interesting object. At this age, babies do not heavily weight social cues and cannot override the cue of perceptual salience to learn the name of the boring object. However, the influence of perceptual salience declines in weight until, by 19 and 24 months of age, it no longer determines whether a child will learn a word. Instead, social cues such as eye gaze (at which object the speaker is looking) come to have more and more importance in the word-learning coalition. Could neuropsychological techniques offer convergent data that demonstrate attention to different cues over time?

An additional first-tier principle is *extendibility*. This is the knowledge that a word does not label only the original exemplar but also a group of similar objects. As Molfese, Morse, and Peters (1990) have done in their work, this principle could be studied by teaching a new object label and testing the breadth of children's brain responses to nonidentical items in the same category. Are young babies' lexical categories narrower than those of older babies or are they the same? What effect does exposure to multiple representations of the same category during training have on brain responses? And, using brain responses, can we begin to narrow down when babies rely more on some features, such as shape, over others for generalizing a novel word?

Finally, the last first-tier word-learning principle is *object scope* (Markman, 1989, has a similar principle called *whole object*). Object scope has two components. First, it states that children will interpret a label as applying to a whole object and not to the action in which the object is involved. Second, it states that a label applies to a whole object over the parts or attributes of an object (e.g., color). Once again neuropsychological experiments could help trace the development of this principle. Young children would first be taught the name of a novel object that had some prominent part (or some unusual property). Will children show an ERP mismatch effect on hearing the name they have been taught and seeing only the prominent part of the original object? Will they show a mismatch effect on hearing the novel name and seeing another object that has the same unusual property as the original object? Clearly, there are an infinite number of exciting questions to address in the arena of how children at different ages learn words.

Learning a hookup between a referent and a word, however, is only part of the story of word learning. After children find a word, they have to discover what category it is in. Guided distributional learning is the method of choice as the baby begins to note the little particles or words that tend to precede or follow words of a certain class. Some researchers are already looking at neuropsychological data to examine whether and when infants begin to notice the word particles that signal part of speech. Shafer, Shucard, Shucard, and Gerken (in press), for example, used a tone-probe ERP method to show that by 11 months of age babies are sensitive to the phonological and distributional properties of the closed-class morpheme *the*. The tone-probe method assumes that lower amplitudes to tones played during passages means that more neuronal resources are being allocated to processing what is being heard. When a number of function words (e.g., *was, is, the, a*) were replaced by nonsense syllables (e.g., *ki, bu, ko, gu*), 11-month-olds (but not 10-month-olds) showed significantly lower amplitudes to the modified passage than to the natural passage. Thus, probably without understanding the function of *the* in the sentence, by 11 months of age babies are beginning to recognize and store repeated word forms that will presumably help them to segment the stream of speech and categorize the words that fall out.

The form-class category of a word can also be signaled by its syntactic role. Thus, babies will need to become sensitive to the syntactic frames that surround words to figure out the part of speech of the word. By around 2 years of age, we found in our lab that babies are sensitive to the syntactic frames that signal that a new word is a noun, adjective, or verb (Golinkoff, Schweisguth, & Hirsh-Pasek, 1992). Using Molfese et al.'s (1990) match–mismatch paradigm, early form-class sensitivity could be studied neuropsychologically.

There are also important transitions in the acquisition of the lexicon that could be profitably studied. Some of this work (Mills, Coffey-Corina, & Neville, 1997; Molfese, Wetzel, & Gill, 1993) has already begun. Studies in early word learning allow us to plot how children begin to break through the word barrier in lexical comprehension. Molfese et al. (1993) asked mothers what words their 12-month-old children knew and what words they did not know. Mills et al. (1997) asked the same question of mothers of children between 13 and 17 months of age. Mothers are apparently superb judges of their babies' comprehension capabilities at this early stage because babies' ERPs were reliably different for these two sets of words. Recall that at the tender ages of 12 and 13 months, most of these are not words that children can yet say. Thus, ERP data give us information about children's burgeoning language comprehension before they can produce more than one or two words. Many tantalizing questions remain. For example, what happens to the wave forms when these words enter into the children's production vocabularies? Once infants organize the articulatory and acoustic pieces for production, however imperfectly, do representations for these words in the brain change as well, with motor areas giving more of a response? How does the wave-form profile change over time as a word enters a child's comprehension vocabulary? How many exposures does it take at around 1 year of age for the wave form to change into the one for familiar words? Does the number of exposures needed for the word to give a familiar looking wave-form change with lexical development? Such questions are a fraction of those that could be addressed with current neuropsychological techniques.

In sum, the primes that feed into word learning are both the phonological forms that emerge from the prior phase of phonological and prosodic analysis as well as the immature word-learning principles. The process of guided distributional learning is a part of the word-learning story as children uncover the part of speech to which novel words belong and how they are to be used. Finally, there are any number of fascinating transitions that might be studied using neuropsychological techniques in the domain of early word learning and the principles that may guide it.

Syntactic Development

The nature of the primes for syntactic development very much depend on one's theoretical camp. For example, inside-out theorists are likely to believe that children come by much of syntactic structure innately. Outside-in theorists emphasize how children construct grammar as they go along. In either case there are certain grammatical primes that are shared by every theory of language acquisition. One prime is attention to grammatical morphemes (e.g., *the, ing, s*). These closed-class grammatical elements were probably found through the guided distributional learning in the last phase.

A second prime is that children must pay attention to word order. Slobin (1985) wrote that "order is so essential to human language that an organism unequipped to notice and store sequential information could hardly acquire such systems" (p. 1192). Even in languages that are relatively order-free, such as Walpiri, which is spoken in Australia, particles that specify particular concepts are inserted in specific orders. Attention to order must therefore be a prime for syntactic learning.

Grammatical morphemes and functor words. There are words in the language, indeed in any language, that play primarily grammatical roles. These *closed-class words* are a relatively small class of words that do not often admit new members. Speakers of English, for example, do not invent new connectives or new prepositions, although they do invent new open-class words all the time (e.g., "Did you *fax* him?" "Isn't it *rad*?") Despite the fact that they are pronounced with low stress, closed-class words do the dirty work of holding sentences together. Consider the poem *Jabberwocky* by Lewis Carroll (1867):

Twas brillig, and the slithy toves did gyre and gimble in the wabe:
All mimsy were the borogroves and the mome raths outgrabe. (lines 1–4)

Although Jabberwocky is filled with nonsense words it seems to make sense. Why? Despite the fact that the content, or *open-class words,* are unknown to us (*slithy, mome*), the grammatical morphemes surrounding them make them seem like English. These little words and particles on words serve as the glue that holds this nonsense poem together. For example, the conjunction *and* encourages us interpret what comes on either side of the *and* as entities or actions of some sort. The article *the* that precedes the word *wabe,* for example, tips us off to the fact that what follows is a noun. The plural ending *s* on some of the words (*borogroves, toves*) also tells us that these new words are nouns. Given that *toves* is a noun, we are able to guess that the word *slithy* that precedes *toves* is an adjective. Therefore, although we are unsure of what this poem is saying, we can easily interpret it at some level by using the grammatical elements and particles that are so important for conveying meaning in English.

When do babies become sensitive to these grammatical elements and particles? When do babies know about their functions? Think of what babies would gain if they were aware of these elements even though they could not yet use them in their own speech. These little words and elements give us, as adults, important clues to what kinds of words they signal.

How could we test to see if babies not yet producing grammatical elements such as *the* and *ing* in their own speech are sensitive to them and expect them to be present? Take the article *the,* which is not included in children's two-word speech. Shady and Gerken (1995) conducted a study with 25-month-olds in which they showed babies picture books with four familiar pictures on each page (e.g., a dog, a chair, a book, and a truck). Babies were given one of four kinds of requests to point to a picture in the book. For example, the experimenter said one of the following:

1. "Find *the* dog for me!" (normal sentence).
2. "Find *was* dog for me!" (familiar English functor word used incorrectly; ungrammatical condition).
3. "Find *gub* dog for me!" (nonsense word; anomalous condition).
4. "Find dog for me!" (functor omitted altogether).

The first sentence then, provided a kind of baseline against which responses to the other types of sentences could be compared. Was the babies' ability to point to objects and animals disrupted when they heard a nonsense word or a misplaced grammatical morpheme instead of the expected *the?* If babies' ability to point to the pictures declined when they heard the strange commands, Shady and Gerken could argue that babies are aware of the article *the* even though it is not yet present in their own speech.

Not surprisingly, babies pointed to the requested picture with the greatest success when they were asked with the normal sentence (#1). Babies were correct 86% of the time, an excellent performance for toddlers! Their next greatest success (75% correct) was with the sentence in which *the* was omitted altogether (#4). Thus, babies seem to have noticed that the obligatory *the* was omitted but it did not seem to disrupt comprehension very much. What did bother them, however, and seriously disrupted their ability to point to the correct picture, were sentences containing a misplaced but perfectly legal word of English (#2) as well as the presence of a nonsense word (#3) where *the* belonged. To those questions, they were only able to get 56 and 39% correct, respectively.

These are intriguing findings. They suggest that, although children are not yet saying articles, they expect them to be there. They notice when they are missing, and they notice when a word they have heard many times before (*was*) is used inappropriately. Furthermore, they are seriously distracted (39% correct) when a nonsense syllable takes the slot reserved for *the*. Once again, using the route of comprehension, there is evidence that babies are far more sensitive to language and its nuances than they show us in their language productions. What would parallel neuropsychological data show? Can we extend this work and the work of Shafer et al. (in press) to test babies' sensitivity to the grammatical morpheme *the* in sentential context?

Perhaps sensitivity to *the* is to be expected because it is so common in speech. Perhaps if we were to test for other grammatical elements, especially ones that get tacked onto words rather than are freestanding like *the,* babies would not appear to be quite so precocious. Could we show, for example, that babies are sensitive to a particle such as *ing* that gets attached to the ends of verbs? Golinkoff, Hirsh-Pasek, and Schweisguth (in press) have examined that very question. Using the IPLP, children between the ages of 18 to 21 months who were not yet producing *ing* in their own speech, were shown four pairs of actions carried out by the same woman. The female voice emanating from the center of the screens exhorted children in infant-directed speech, "Find dancing! Where's dancing?" This was the normal, control condition, and, for us to make sense of the rest of the conditions that contained manipulations of *ing,* children had to show us that they comprehended *dancing* and *waving*. Two other groups of toddlers saw the same videotapes and heard either "Find dancely! Where's dancely?" or "Find dancelu! Where's dancelu?" *ly* is an acceptable English morpheme used on adverbs. However, it does not appear on the ends of verbs. Would children's sentence processing be disrupted in the *ly* condition, thereby indicating that they detected the anomaly of the misplaced *ly? lu,* on the other hand, is a nonsense syllable that is not a familiar morpheme and cannot end an English word. Would children's sentence comprehension be further disrupted in the presence of a nonsense ending?

Children had no trouble comprehending the sentences containing the normal verbs (e.g., *dancing*). They watched the matching screen significantly more than the nonmatching screen. In the *ly* condition, they detected the inappropriate placement of *ly* at the end of a verb. They did this by systematically watching the nonmatch (*turning*) during the first pair of verbs and then by watching the match for the remaining three pairs of verbs. It was as if children decided that *ly* could end English verbs, after all. The children who heard *lu* had their comprehension of these familiar verbs disrupted throughout testing. They paid no more attention to the matching than to the nonmatching screen. Taken together, these results tell us that, prior to the time when children are producing *ing,* they are already analyzing it. Furthermore, they seem to be distinguishing the word stem from the grammatical ending. If they were just relying on the stem of the verb (e.g., *dance*), they would match the matching screen in all conditions, ignoring the endings. Thus, we have evidence from yet another study that children not yet producing a morphological structure, in this case a bound morpheme, are aware of it and are analyzing it before they produce it.

Both of these studies, Shady and Gerken's (1995) on *the* and Golinkoff et al.'s (in press) on *ing,* beg to be followed up using neuropsychological techniques. Would brain responses to sentences paired with short videos of action be different if the verb used was normal, ungrammatical, or anomalous? Would the brain show us a distinct response to such conditions in babies this young or younger?

Apparently the answer is *yes*. The data just described are supplemented beautifully by an ERP data conducted by Mills and Neville (1996) on function words. Using babies 20 months of age, Mills and Neville found that closed-class words such as *more* and *mine* are treated differently in the brain than open-class words, depending on the size of the baby's vocabulary. Babies with vocabularies greater than the 50th percentile on the MacArthur Inventory—babies who had already had their vocabulary spurt—had ERPs that differed by 200 msec after word onset to these classes of words. Babies who had MacArthur scores below the 50th percentile and knew fewer than 100 words did not show ERP differences to open and closed-class words, although all babies knew all the words used.

Notice how well these three studies converge. Taken together, their findings suggest a precocious sensitivity to grammatical morphemes, to grammatical primes, that is not necessarily reflected in production until months later.

Sensitivity to word order. The second prime for grammatical learning is attention to order information. Hirsh-Pasek and Golinkoff (1996a) found, using the IPLP, that babies between the ages of 16 to 18 months, some of whom had only two words in their productive vocabulary, were sensitive to word order in five- and six-word sentences.

Babies saw the same action taking place on each screen but with who was doing what to whom reversed. On one screen, for example, Big Bird was tickling Cookie Monster while on the other screen Cookie Monster was tickling Big Bird. The linguistic stimulus (e.g., "See Big Bird is tickling Cookie Monster!") matched only one of these highly similar events. If babies understood the linguistic stimulus, they should watch the event that matched what they were hearing longer than the event that did not match. Results indicate that this is just what infants did; they watched the matching screen over four pairs of different events, regardless of how advanced their language was. When do children attain this sensitivity? If neuropsychological techniques could be used to expand our understanding of children's attention to word order, we would be on the road to tracing the development of the first syntactic device English-reared children use in their own speech. Does this capability only emerge after children have attained a certain number of receptive vocabulary items? Does this capability herald another transition into grammatical comprehension?

Notice that if babies pay attention to word order and to closed-class morphemes, they have two predictable and reliable cues to syntactic structure. Armed with these primes and supplemented by guided distributional learning, children could go pretty far in constructing the grammar of their language.

What transitions are ripe for examination using neuropsychological techniques in grammatical learning? Let us return to the "Mommy sock" utterance for some clues. Almost 30 years later, there is still no definitive answer to this question of structure, although we have come at least part way. The Cookie Monster study (Hirsh-Pasek & Golinkoff, 1996a) shows that children at least seem to be able to use semantic relations in interpreting sentences. We can therefore rule out the possibility that children are simply putting words together with no underlying structure at all.

Can we say whether babies are using syntactic relations such as subject and object or do babies have to transition into this level? If they respond to passive sentences, such as "Where's Big Bird being tickled by Cookie Monster?" where the action roles are the same but the subject of the sentence is no longer in the first position, we would say *yes*. This is an important transition in grammatical learning, and it poses a central question that remains in the study of grammatical development. When, as Gleitman (1981) wrote, does the tadpole of semantics turn into the frog of syntax or is it frogs all the way down? Neuropsychological data could be very informative on this question.

In sum, there is evidence that children begin learning grammar armed at least with the developmental primes of grammatical morphemes and sensitivity to order. Neuropsychological data could add greatly to our understanding of how grammatical development proceeds and help us to resolve long-standing as well as newer questions about grammatical capabilities.

CONCLUSION: FINDING THE MISSING NEUROPSYCHOLOGICAL PIECES FOR THE LANGUAGE DEVELOPMENT PUZZLE

Our position is that there are any number of fascinating issues in the field of language acquisition that can be attacked using brain response data. However, we must also offer three caveats that speak to the same point. First, if neuropsychological data are to be incorporated into the mainstream of language acquisition, researchers must be educated on how these data are collected and what they mean. Researchers who work outside the area are sometimes distrustful of neuropsychological data and need to be shown, both in presentations at meetings and in the literature, about how useful such data can be to the study of language acquisition.

Second, to maximize the important research emerging from a number of laboratories, this research should be squarely placed within the latest theorizing in language acquisition and in journals (e.g., *Journal of Child Language*) that are read by the majority of researchers who work in the area of language acquisition.

Third and finally, collaboration across laboratories that use behavioral and neuropsychological measures is a prime way to accomplish the lofty goals detailed herein. Such collaboration would also allow for the convergence of methods that is so powerful in focusing on a common problem. In addition, corroboration and extension of behavioral data with neuropsychological measures would go a long way toward demonstrating the utility of neuropsychological studies.

The potential that neuropsychological studies have for broadening our understanding of old as well as new problems in the field of language acquisition is enormous. Allow us to assume an optimistic vantage point. Data resulting from applications of the headturn preference procedure, the IPLP (and its new 3-D variant), and the match–mismatch habituation method have forced us to rethink the developmental primes and transitions underlying language development. Perhaps neuropsychological data can be the next wave of innovation, prompting the field to modify further our theories of language acquisition by enriching the picture of early development in significant and informative ways. Neuropsychological data could provide the field with some of the missing pieces needed to put the puzzle of language acquisition together.

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