

Hybrid Theories at the Frontier of Developmental Psychology:
The Emergentist Coalition Model of Word Learning as a Case in Point

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Running Head: Hybrid Theories of Development

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...there are no single effective pushes to the developing system, but rather a combination of influences that lead to observable change (Nelson 1996, p. 85).

The flourishing new domain of cognitive science needs to go beyond the traditional nativist-empiricist dichotomy that permeates much of the field, in favor of an epistemology that embraces both innate predispositions and constructivism (Karmiloff-Smith, 1992, p. 193)

The nature of early word learning is a paradigmatic and contentious case of the nature-nurture debate. How do infants break through the language barrier with their first words at around 12 months of age? And what accounts for the transformation in word learning at around 19 months of age when a slow, laborious process turns into one in which infants learn up to 9 new words a day (e.g., Carey, 1978; but see Goldfield & Reznick, 1990)? As in other areas of developmental psychology, a number of theories have sprung up to address these controversial questions. Some argue that word learning is a product of all-purpose learning mechanisms like associationism and generalization (Smith, 1999, 2000). Others suggest that word learning must be accounted for through internal constraints on the learning process (Markman, 1989). Still others hold that the social environment navigates word learning *for* the child (Akhtar & Tomasello, 2000). In each case, theorists contend that the most parsimonious explanations of learning come

from reduction to *either/or* theories. Either the mechanisms for learning are social and from the environment *or* are constraints that emanate from the child's head. The present data illustrate that word learning begins as an associative process and gradually turns into a process dependent on social cues. Between 10 and 19 months, infants come to appreciate the role that social cues play in word learning. They do not, however, start out that way. Prior research by Hollich, Hirsh-Pasek, & Golinkoff (2000) showed that 12-month-olds avoided mismatching and were sensitive to but did not recruit social cues as the 19 months to 24 months old did. The question that remained was whether infants start out as associative animals only later recognizing the import of the social cues that have been available all along.

Here we present a hybrid theory that pulls from both environmental and constraints approaches while at the same offering a developmental account of the word learning process. The emergentist coalition model of word learning (Hirsh-Pasek, Golinkoff & Hollich, 2000; Hollich et al., 2000; Golinkoff, Hirsh-Pasek & Hollich, 1999) suggests that infants are biased to attend to and integrate multiple pieces of information as they learn words. Current theories of word acquisition that emphasize either environmental or nativist approaches provide only *snapshots* of learning at different points in developmental time. In the emergentist coalition model, these snapshots are integrated in a theoretical model that takes change over time seriously. Such emergentist models are appearing throughout the developmental literature in domains of spatial development (Newcombe & Huttenlocher, 2000), number theory (Gelman & Williams, 1998) and language development (Hirsh-Pasek & Golinkoff, 1996; MacWhinney, 1999). These theories force us to reconsider the age-old link between parsimony and

reductionism in favor of systems-based, dynamic models that include multiple inputs to complex processes (Thelen & Smith, 1994). These newer theories occupy what Newcombe and Huttenlocher (2000) have called the “radical middle” in psychology, forcing an empirically testable balance between nature and nurture.

In this paper, we explore the word learning problem, the three theories that have been proposed to address the key questions in the field, and an attempt at a reconciliation in the emergentist coalition model of word learning. Data on word reference and word extension will be used not only to support the theory, but to demonstrate how those working on word learning might rethink the concept of developmental change.

Three Theories of Word Learning

The Quinean conundrum (1960) provides a cornerstone for the word learning problem. To learn a word, infants must first segment the sound stream, discover a world of objects, actions, and events, and then map the word from the sound stream (or visual stream in sign languages) onto the referent. Quine’s now famous story highlights the inherent difficulty of this so-called mapping problem: A linguist in a foreign land sees a rabbit scurrying by while hearing a native exclaim “gavagai!” Among other things, the word “gavagai” could refer to the whole rabbit, the rabbit’s ears, or to the rabbit’s hopping. The world provides an infinite number of possible word-to-world mappings. How is a child to learn how the word maps onto the referent?

Theories of word learning can largely be defined by whether they embrace the Quinean conundrum as a foundational assumption or whether they reject it. Theories that posit constraints or principles adopt Quine’s view of the problem space. Theories that emphasize social input or associative learning consider Quine’s example largely

irrelevant to the problem of word learning. These theories form the landscape for the debate about the nature of early word learning.

Constraints or principles theories take Quine seriously. Because word to world mapping is under-determined, human minds must be equipped with constraints or principles that narrow the search space. Under this theory, children approach the word learning task biased to make certain assumptions over others for what a word might mean. Domain-specific constraints theories have been posited for a number of cognitive development domains. As Gelman and Greeno (1989) wrote with respect to theories of number development,

If we grant learners some domain-specific principles, we provide them with a way to define the range of relevant inputs, the ones that support learning about that domain. Because principles embody constraints on the kinds of input that can be processed as data that are relevant to that domain, they therefore can direct attention to those aspects of the environment that need to be selected and attended to (p. 130).

Similar statements have appeared in the literature on spatial development (Newcombe & Huttenlocher, 2000) and object perception (Spelke, 1990). The general thrust of the constraints or principles position is to make a daunting task manageable by restricting the number of hypotheses the learner need entertain to arrive at a representation of a domain.

A substantial body of evidence has accumulated to support the constraints position in word learning. Markman's (1989) principle of mutual exclusivity, for example, states that children assume that an object can have only one name. The consequence of this principle is that a novel name will not label an already named object

but rather will label an unfamiliar object. Golinkoff, Hirsh-Pasek, Bailey and Wenger (1992) (see also Mervis & Bertrand; 1994, Evey & Merriman, 1998), have shown that 28-month-olds will assume that a novel label maps to an unnamed object when presented with a set of familiar and unfamiliar objects. These findings not only support Markman's mutual exclusivity principle but also a more flexible principle ("novel name-nameless category" or N3C) posited by Golinkoff, Mervis, and Hirsh-Pasek (1994). Similarly, Clark (1983) suggested that children operate with a principle called "conventionality": Use the word that your linguistic community uses or you won't be understood. Mervis (see Golinkoff et al., 1994) provided numerous diary entries which showed that children abandon their idiosyncratic terms in favor of the standard terms (e.g., over time "pops" becomes "pacifier").

The principles/constraints theories have flourished. Indeed, over the last 15 years, there has been a proliferation of principles including Waxman and Kosowski's (1990) "noun-category bias," Markman's (1989) "mutual exclusivity," Markman and Hutchinson's (1984) "taxonomic assumption," and Clark's (1983) pragmatic constraint of "contrast." These principles were reviewed and placed in a developmental framework by Golinkoff et al. (1994) who posited a set of six principles (some new and some in the literature) that were necessary and sufficient to account both for how children get word learning "off the ground," and for how they become "vacuum cleaners for words" (Pinker, 1994) at around 19 months of age.

The Golinkoff et al. framework offered a developmental model in which the principles of word learning were organized on two tiers that captured the changing character of word learning (see Figure 1). On the first tier, and appearing at around 12

months of age, were principles like reference (that words map to objects, actions, and events); extendibility (that words do not uniquely refer to the original referent but rather to a category of objects, actions and events); and object scope (that words refer to whole objects rather than to object parts and to objects over actions) (See also Markman's (1989) whole object principle.) On the second tier, the principles of N3C (that novel names label novel categories); categorical scope (that words label taxonomic categories); and conventionality (Clark, 1983) (use socially agreed upon names for things) are born from the first tier principles and help children catapult into the mature word learning characterized by the vocabulary spurt. Fundamental to the principles framework is the idea that the *principles themselves undergo change with development and are an emergent product of the combination of word learning experience and some inborn biases*. Nested in the Golinkoff et al. (1994) framework is a powerful developmental solution to the Quinean dilemma.

-Insert Figure 1 about here-

Social-pragmatic theorists stand in stark contrast to the constraints position. Children, embedded in a social nexus, are guided by expert word learners as they embark upon the word learning task. As Nelson (1988) has written, Quine's problem becomes irrelevant,

The typical way children acquire words...is almost completely opposite of the Quinean paradigm. Children do not try and guess what it is that 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 (pp. 240-241).

Bloom (1993, 2000) similarly concludes that adults talk about objects, actions and events that are *relevant* to children. Children don't have to wade through alternative interpretations for a word; the correct interpretation is already the focus of their attention.

There is considerable evidence that children are capable of utilizing social cues in the service of word learning. For example, Tomasello, Strosberg, and Akhtar (1996; Tomasello & Barton, 1994, Carpenter, Nagell, & Tomasello, 1999; Akhtar & Tomasello, 2000, Baldwin & Tomasello, 1999) showed that 18- and 24-month-olds can use the intention of the experimenter to attach a label to a novel object or action. If the experimenter indicates that she erred in using a label, children will not attach a novel label to the first object or action they see but to the second. Akhtar and Tomasello (1996) showed that 24-month-old children can mine the social context to attach a novel label to a hidden object instead of to novel objects that they are shown. Furthermore, Baldwin, Markman, Bill, Desjardins, Irwin, and Tidball (1996) showed that 18-month-olds can evaluate whether an adult uttering a label in great excitement ("It's a toma!") while on the telephone is intending to label the object they are playing with or something else. Young children are not fooled into forming a link between a label uttered by a woman not addressing them just at the moment that they are focused on a novel toy.

Under the social-pragmatic view, children are seen as skilled apprentices to expert word learners participating in a structured social world. Children are also seen as able to read the social intent of their mentors (P. Bloom, 1999) in this world. By virtue of being a social animal then, language comes for free. Under this interpretation, Quine's linguist differs from real children because children are immersed in rich social contexts that naturally delimit the possible mappings between words and their referents.

The constraints/principles and the social-pragmatic theories of word learning represent the most common positions in the literature. Recently, however, a third position, outlined by Smith (1995, 1999, 2000), Samuelson and Smith (1998), and Plunkett (1997) offers a third perspective on the word learning problem. The domain-general view of word learning rejects Quine's conundrum, suggesting that word learning can be best accounted for through "dumb attentional mechanisms" like perceptual saliency, association, and frequency. In comparing the differences in constraints theories and her own systems theory view, Smith (1995) wrote,

The empirical focus [of constraints theories] becomes not the processes that enable children to interpret words in context, but whether children's biased learning has the properties needed to 'solve the induction problem.' The present thesis is that the induction problem is irrelevant to developmentalists. Learning is not necessarily hypothesis testing. Development is not induction (p. 4).

Children do not need constraints or principles to forge word-to-world mappings. The process of mapping a word onto an object is straightforward. Children notice objects, actions, and events that are the most salient in their environment. They associate the most frequently used label with the most salient candidate. In this way, ambiguity in the word learning situation is removed. General cognitive mechanisms are sufficient not only to account for how young children first map words onto referents, but also can combine in ways to account for the complexity of more sophisticated word learning (Smith, 2000).

This synopsis of the theoretical debate in the area of word learning parallels that seen in the developmental literature. For any given developmental problem space, theories arise that represent the domain specific constraints alternative, a social-pragmatic

or cultural alternative, and an associationistic alternative. As in the area of word learning, there is mounting data to support each of the positions. There are also reasons to reject each theory. By way of example, one could argue that despite many attempts to sweep away the Quinean problem in word learning, it refuses to disappear. Any single object, action or event presents an array of possible referents to be named. Even something as simple as a “sippy cup” has a lid, an elevated portion on the lid (mouthpiece) and possibly pink flowers on its blue plastic base. All of the parts move together when the cup is lifted and some of these parts -- such as the mouthpiece -- may prove more salient than the whole object. Which of these parts is graced with the name, “cup?” Neither perceptually based nor socially based theories assist the child in reaching the final determination of what makes word-to-world mapping possible. Only the constraints or principles theories solve the Quinean problem. Yet, they do so by default. Either they assume that principles come in full-blown and are non-developmental (Markman, 1989) or they offer a developmental perspective with little emphasis on the mechanisms of change.

The debate presses on (Golinkoff, Hirsh-Pasek, Bloom, Smith, Woodward, Akhtar, Tomasello & Hollich, 2000) as scientists try to determine which theory best accounts for the data. Yet, science’s steadfast and historically rooted view that parsimony demands a *choice* of one theoretical explanation over the other might lie at the root of the problem. Perhaps the issue should not be cast as *which* of the particular theories is “right.” Perhaps the issue should be recast as which components of which theories seem to govern children’s word learning at different points in the course of development? This reframing of the question requires the creation of a hybrid approach

with clear hypotheses that make the theory empirically testable. The idea that we need to consider multiple perspectives for complex problems is not new (Bloom & Lahey 1978, Bloom 1993, 2000). It was from this idea that the emergentist coalition model was born.

The Emergentist Coalition Model of Word Learning

The emergentist coalition model of word learning is a hybrid model that builds on the developmental lexical principles framework (Golinkoff et al., 1994). This model (Hollich et al., 1998; Golinkoff et al., 1999; Hollich, Hirsh-Pasek & Golinkoff, 2000) incorporates the impact of diverse factors on word learning because, as in the real world, it is likely that children avail themselves of social, attentional, cognitive, *and* linguistic cues to learn new words. The emergentist coalition model embraces this complexity. It allows for the full range of cues to word learning, rather than forcing artificial choices among them. Thus, the first defining tenet of the model is that children mine a coalition of cues on their way to word learning. Figure 2 graphically depicts the multiple inputs that are available for word learning.

- Insert Figure 2 about here -

Although a range of cues is always *available*, not all cues for word learning are equally *utilized* in the service of word learning. Younger children, just beginning to learn words, rely on only a subset of the cues in the coalition. Older, more experienced word learners rely on a wider subset of cues and on some cues more heavily than others. The model posits that social cues such as eye gaze that are subtle and may demand at least a primitive theory of mind, will be less utilized than a cue such as the salience of objects. Given a choice between attaching a novel name to a boring object that an adult is looking at versus a colorful, exciting object, the child just beginning to learn words

should rely on perceptual salience (consistent with the associationist) before relying on the subtle social cue of eye gaze (consistent with the social-pragmatic perspectives).

Thus, the second major tenet of the theory is that the cues for word learning *change their weights* over developmental time. Figure 3 graphically depicts how reliance on these cues shifts with development.

- Insert Figure 3 about here -

Because children make differential use of the available cues with development, this model holds that principles for word learning are emergent. They develop over the course of the second year of life as children gain word learning experience. Unlike other constraints posited in the literature, the emergentist coalition model states that not all of the principles are available from the start of word learning (see also Waxman, 1999, whose “noun-category bias” evolves with exposure to linguistic structure). Lexical principles are the products and not the engines of lexical development. Children do not start word learning, for example, with the novel name - novel category principle (N3C). Mervis and Bertrand (1994) have shown that the N3C principle is not in place until after the vocabulary spurt. The third tenet of this model, then, is that the principles for word learning are emergent and not given a priori.

The developmental cast of this model makes it imperative to study the origins of word learning as well as the transformation that takes place in the second year of life when the child becomes an expert word learner. Data need to be collected that demonstrate that children detect and utilize multiple cues for word learning; that their reliance on these cues changes over the course of development; and that principles for word learning emerge from word learning experience.

Our research has assessed these claims within the context of the first tier principles of reference (that words map onto the child's representation of objects, actions and events) and extendibility (that words map onto more than one exemplar). First, we hypothesized that children learning their first words (at 10- or 12-months of age) would be informed by multiple cues, attentional, social, and linguistic. Second, we hypothesized that perceptual salience would be more heavily weighted than social cues for the novice than for the expert word learner. Third, we hypothesized that the word learning principles themselves develop along a continuum from immature to mature such that children are first attracted by what is most salient to them, and only later note what is important to the speaker. As they break through the language barrier, children are guided (though not completely) by associationist laws. As they mature into veteran word learners, they are guided (though not completely) by social-pragmatic strategies. Both views are united under one theory.

Evidence for the Emergentist Coalition Model

Investigation of the hybrid model demanded experiments that could trace development of the principles of reference and extendibility from their immature to their mature states. To assess the principle of reference, we examined whether infants would attach a label to both interesting and boring objects. We reasoned that a child with an immature principle of reference might attach a novel label to the interesting object -- regardless of which object an adult was labeling. The child with a mature principle, on the other hand, should overcome the salience of the object in favor of relying on the speaker's social cues to what is being labeled. To assess the principle of extendibility, we first asked whether infants would extend a label for a given object to one that differed

only in color from the original exemplar. We then put infants in a very difficult task and asked whether they would use social information to extend that label to an object that bore no resemblance to the original object. After all, bean bag chairs and dining room chairs bear little resemblance to one another and yet they are both called, “chairs.” Children who fail to extend a label or who will only extend the label to close perceptual relatives possess an immature principle of extendibility. Alternatively, children who trust the social mentor extending a label in the face of contrasting perceptual cues are operating with a mature principle of extendibility.

Examination of the emergentist coalition theory required a method that could be used equally effectively with children in the age range of interest (10 to 24 months) and one that would enable researchers to manipulate multiple cues (attentional, social and linguistic) and their interactions. The Interactive Intermodal Preferential Looking Paradigm (IIPLP) provided this new method (e.g., Hollich et al., 2000). Based on the “Intermodal Preferential Looking Paradigm” (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1987; Hirsh-Pasek & Golinkoff, 1996) used to study lexical and syntactic comprehension, Baldwin’s (1991, 1993) “bucket task,” and Fagan’s (1971; Fagan, Singer, Montic, & Shepard, 1986) infant intelligence test, the method allows for the study of multiple cues to word learning in the first two years of life. The physical set up is depicted in Figure 4.

- Insert Figure 4 about here -

Infants are seated on their blindfolded mother’s lap facing the experimenter and our testing apparatus. After pre-exposure to the toys – a pair of familiar toys on some trials and a pair of novel toys on others -- the toys are fixed with velcro onto one side of a

two-sided black board that can be rotated so that the toys can go in and out of view for a specified period of time. The experimenter hides behind the board while children are inspecting the toys and during test trials. Coding is done off-line from video taped records.

Using this apparatus, it is possible to examine word learning in a controlled setting. Familiar object trials allow us to ask whether the child can “play our game.” The use of unfamiliar, novel objects permits exploration of the cues and *combinations* of cues that children use to guide word learning across development. The logic of the design (Golinkoff et al., 1987; Hirsh-Pasek & Golinkoff, 1996), is that children should look more at an object that “matches” the linguistic stimulus than at an object that does not match. Thus, the dependent variable is visual fixation time to the target (named) object versus to the unnamed object.

Validation of the method comes from the familiar trials. Children at three ages were tested: 12- to 13-month-olds just at the beginning of word learning; 19- to 20-month-olds who may or may not have yet experienced a vocabulary spurt; and 24- to 25-month olds who typically have sizeable production vocabularies. In over 23 experiments children demonstrated the potency of the method by looking significantly more at the target item than at the non-target item in the familiar condition when an item was requested (Hollich, et al., 2000). Evaluation of the hypotheses comes from children’s responses to novel stimuli. Using this method, we were able to explore how infants move from an immature to mature principle in reference and extendibility and to examine the hypotheses that form the foundation for the emergentist coalition model.

Evidence from the studies on reference

Reference, or the assumption that words refer, is the most basic of the word learning principles. Do infants assume that a word refers to an object, action or event? How do they choose which object, action or event should receive the label? To investigate these questions conditions were created in which multiple cues were available to children but were sometimes placed in conflict. In what we called the coincident condition, we labeled the novel toy that coincided with children's preferences -- the interesting toy. In the conflict condition, we labeled the novel toy that did not coincide with the children's preferences -- the boring toy. We reasoned that learning the word in the coincident case should be easy for children because all of the "cues," attentional, social and linguistic, were in alignment. In contrast, learning a novel word in the conflict condition should be more difficult because the coalition of cues is not acting in concert.

The experiment was conducted in four phases. First, children were given the opportunity to explore both the interesting and boring toys. Second, children participated in a salience trial in which they saw both the interesting and boring toy mounted side by side. Third, in the labeling phase, the experimenter captured children's attention, displayed both toys and labeled the target five times with a novel word (e.g. danu). In the coincident condition, the experimenter looked at and labeled the interesting toy; in the conflict condition, she looked at and labeled the boring toy. Finally in the test trials, the experimenter, now hiding behind the board, asked for the object that was labeled during training, once again getting the child's attention first, e.g., "Eve, where's the danu?" If

children learned the name of the correct toy, they should look more to the target than to the non-target (see Hollich et al., 2000, for details).

What cues do children use to determine the reference of a word? The participants were 32 children at each of 12, 19 and 24 months of age. At all three ages, there is evidence that children detected the range of cues available. For example, even the 12-month-olds detected the social cue of eye gaze although they could not use it when it was in conflict with perceptual salience. By way of example, they learned the name of the object only in the coincident condition, as several further studies indicated (Hollich et al., 2000). The 19-month-olds learned the names of the objects in both conditions, but were still influenced heavily by perceptual salience. Even the oldest group who learned the names of the novel objects in both the conflict and the coincident conditions still showed the effects of perceptual salience by looking much longer at the target object in the coincident condition than in the conflict condition. This suggests that 19-month-olds were lured by the perceptual salience of the interesting toy, but were able to overcome it when the boring toy was the focus of the experimenter's attention. In short, these data suggest that infants with an immature principle of reference are more dominated by perceptual salience than are their counterparts with a more mature principle of reference. Nineteen- and 24-month-old children use the speaker's social intent (as signaled by their eyegaze) when mapping word to object. In light of these data, we are conducting studies with 10-month-old infants to see whether children who are just beginning to acquire a comprehension vocabulary, operate like the 12-month-olds who are starting to produce language. Preliminary results from this group suggest that 10-month-olds are even more bound to perceptual salience demonstrating a clear preference for the interesting toy even

in the conflict condition. That is, these children do not seem to be thrown by the presence of conflicting social cues. Rather, they seem to be oblivious to them. They seem to assume that labels “go with” interesting rather than boring objects!

What we see in the data is a clear pattern that changes over time such that infants become increasingly less dependent on perceptual cues and more dependent on social cues to determine reference. Such data speak to both the associationist and the social pragmatic theorist. The associationist position would predict that children *would* form a mismatching between the *interesting* object and the label in the conflict condition. If the 10-month-old data stand, then these data fit this prediction – but only for the very youngest children. Yet, by as early as 12 months of age, children with only 3 words in their productive vocabularies are already demonstrating some sensitivity to social information in a word learning task . These children, at the cusp of word learning, learned the novel labels only in the coincident condition. In the coincident condition, the experimenter labeled the object that the babies were most interested in. For these babies, learning took place when the cues coincided. However, when multiple cues failed to coincide in the conflict condition, infants showed little evidence of word learning. They wanted to look at the interesting object despite the fact that the experimenter persisted in labeling the boring object. Though they looked at the interesting object much more than the boring object in the conflict condition, they did not falsely conclude that the novel label was attached to the interesting object. Even 12-month-olds were sensitive to the fact that the experimenter was looking elsewhere and *not* labeling the interesting object. Even 12-month-olds are able to use multiple cues for word learning, and the cues had to *overlap* for learning to occur. While the 12-month-olds are not weighing social cues

heavily yet, their performance also defies the predictions made by the associationistic camp. Only a hybrid theory that talks about attention to multiple cues and shifts in attention to these cues over time can account for the data.

Evidence from the principle of extendibility

Children who master reference must then learn that words generally refer to more than one exemplar. That is, most words do not refer to a single exemplar (e.g., a proper noun), but rather to groups or categories of objects. Two types of theories dominate the literature on extendibility. The “broad to narrow” view holds that words license attention to categories (Hall & Waxman, 1993; Waxman & Markov, 1995; Balaban & Waxman, 1997). Children already have rich conceptual systems by the end of the first year of life (Mandler & McDonough, 1996). They might assume that words map onto these categories from the outset. Note that some theorists argue that the categories need not be perceptually based. For example, Mandler and McDonough point out that airplanes are more perceptually similar to birds than they are to cars and yet infants’ global categories seem to include airplanes and cars but not birds. Indeed, Hall (1991) offers evidence that even 2-year-olds will occasionally interpret proper nouns as common nouns. This position leaves open the question of how infants would ever learn that some words are more narrowly construed (see Hall et al., 2000; Markman & Jaswal, in press; Bloom, 2000, for proposals of how this could occur).

The alternative hypothesis, the “narrow to broad” view, holds that words label individual exemplars and only later generalize to categories either on the basis of shared shape, or on the basis of parental speech patterns which highlight perceptual similarity (Smith, 2000). This view dates as far back as Locke (1690) and the British Empiricists.

Under the narrow to broad view, perceptual similarity plays an important role in categorical extension.

To assess the development of the principle of extendibility, we asked three questions about how children would react when taught a novel label: 1) Will children label just the original object or will they be willing to extend the label to another object of similar appearance?; 2) Can infants extend the label to another exemplar of similar appearance even when the original object is not present?; and 3) Will children use social cues to extend a novel label even in the absence of perceptual similarity? The emergentist coalition model lead us to hypothesize a narrow to broad progression that is distinct from the more perceptually dominated view presented by Smith (2000, see also Keil, 1989). Children might begin with a proper noun hypothesis, assuming that a word refers only to its original referent and cannot be extended to like objects. Later, and similar to Smith's theory, children may progress to a period in which perceptual similarity controls extension. However, Smith's view is that extension based on perceptual similarity (in particular, the shape bias is only firmly in place at 24 months of age). Our principle of extendibility, in contrast, allows for early extension based on perceptual similarity (among other factors). Finally, this perceptual strategy gives way to a social-pragmatic one in which children rely on social and linguistic cues to determine category membership and hence word extension. Under a theory like the emergentist coalition model that allows for interaction of multiple cues and their shifting weights, noun extension that moves from being exclusively perceptually based to being more heavily based on social cues is possible. Under a theory like Smith's (2000) that

emphasizes a single factor (the role of shape in extension) such a shift would not be predicted.

To distinguish between the alternative theories, two experiments were conducted: Perceptual Extension and Social Extension. The perceptual extension study was conducted in four phases. First, children were given the opportunity to play with three objects, two of which were identical except for color (lemon reamers in red and purple), and one which was perceptually distinct and served as the distractor item (a green travel razor holder). Second, children participated in a salience trial in which they saw the two perceptually similar objects mounted side by side. Third, in the labeling phase, the experimenter captured children's attention, displayed only one toy (the red lemon reamer), and labeled the target ten times with a novel word (e.g., "danu"). Fourth, the children participated in three test trials: 1) in the novel trial, the just-labeled object (red lemon reamer) was paired with the dissimilar object (the green razor holder) to ensure that the children had learned the original label; 2) in the proper noun trial, the two similar objects (the red and purple lemon reamers) were placed side by side to test whether infants would look only towards the originally-labeled object; 3) in the extend trial, infants saw the unlabeled category member paired with the out-of-category member (the purple lemon reamer and the green razor holder) to see whether infants would extend the novel word to an item in the same category in the absence of the originally labeled object.

The order of the second and third test trials were counterbalanced across children. During all testing conditions, the experimenter hid behind the board and asked for the object that was labeled during training, once again getting the child's attention first, e.g., "Eve, where's the danu?" If children can extend, they should learn the name for the

original toy, show even looking times in the second test trial and extend the novel name to the category member in the last test trial (Hennon, Hirsh-Pasek, Golinkoff, Rocroi, Arnold, McGuire, Baker & Driscoll, 2000).

Results reveal three patterns of extension depending on the age of the children. Ten- and 12-month-olds showed a proper noun bias with no evidence of word extension. In the novel trials, the majority of the 10- and 12-month-olds did learn the original word. When they did, we examined their performance on the proper name and extension trials. There was no evidence that these infants could extend the newly learned label. On the proper name trials, these infants significantly preferred the originally named object. Further, these same children showed no evidence of extension when the original object was absent, distributing their looking times evenly across the like category member and the completely novel object. We interpret this result to suggest that the younger infants had a proper name bias. Some might argue that infants looked more at the originally labeled object during the proper name trials because it had been made more salient for them during training. We think this explanation is incorrect. Salience should have been equal across ages. As we will see, older children had no problem extending in both the proper noun and extension trials. Thus, 10- and 12-month-old infants seemed to operate with a proper noun bias as if the label referred only to the original object without the ability to extend to other category members.

Fourteen-month-olds showed some progress towards extension. They learned the original label in the novel trials and seemed to be in a transition phase with respect to extension. If the children saw the proper noun trials *first* and then the extension trials, they showed no evidence of extension. They preferred to look at the originally labeled

object in the proper noun trial and demonstrated no evidence of extension in the extension trial. Yet, if they saw the extension trial *first* and then the proper noun trial – they revealed an ability to extend a label to a like category member. These children looked at the like category member in the extension trial and then distributed their looking evenly across both exemplars of the category in the proper noun trial. We interpret this to mean that these children have a fragile principle of extendibility. If they are primed to look at the original object, they will do so. If not, they can demonstrate extension (Hennon, Rocroi, Chung, Hollich, Driscoll, Hirsh-Pasek, & Golinkoff, 1999).

Finally, the 19- and 24-month-olds readily extended the newly learned label. These children learned the novel words, distributed their looking evenly across the two category members in the proper name trial, and readily extended the label in the extension trial. These children had mastered the principle of extendability.

The Social Extension experiment was designed to assess whether infants would extend a label based on social and linguistic cues even when there were no perceptual cues. If mature word learners recruit social information to determine category membership, they should extend a new word to an object that the speaker labels as a category member similar if even the perceptual similarity between this object and the other category members is not apparent to the child. To test for this progression, infants participated in a three phase experiment. First, they were exposed to and played with *five* objects. Three of the objects differed only in color and were given the same name (e.g., three spaghetti measures of different colors were each labeled a “lorbit”). Two dissimilar items were also included in the set (e.g., a coffee grinder and a stirrer) only one of which was labeled a “lorbit.” Second, the two dissimilar objects were displayed side by side on

the testing board to assess salience. Third, infants participated in two test phases: 1) they saw the two dissimilar items (grinder and stirrer) displayed side by side and were asked to, “Find the lorbit.” If they accepted the experimenter’s use of the category label for this perceptually dissimilar object, they should look more to the one that had received the label; 2) the dissimilar object that was not labeled the lorbit (stirrer) was placed alongside one of the perceptually-based category items (spaghetti measurer) while the experimenter said, “Find the lorbit.” This latter trial assessed whether infants had learned the category at all. If they had, they should spend more time looking at the spaghetti measurer.

Sixteen children at each of 13, 19 and 25 months of age participated in this study. All of the children were willing to learn the label for the perceptually similar items. In sharp contrast, the 18- and 24-month-olds, but not the 12-month-olds, were willing to learn the label for the perceptually dissimilar object. That is, the older children were willing to extend the label to the dissimilar object when they were taught it by an adult. The youngest children were not willing to extend the boundaries of this label to include a perceptually dissimilar object. This experiment becomes even more telling in light of a subsequent experiment in which the test objects were altered to offer some perceptual support. In the replication, children saw three like-category objects (lemon reamers in red, purple, and blue) and two test objects that shared a perceptual part with the category items (a lemon juicer which had a distinctly similar juice extractor on top; and a poker that had a perceptually similar handle with the reamers) Here, the 12-month-olds had no problem extending the name “lorbit” to the lemon juicer. These children learned a label and extended the bounds of the object category only when supplied with perceptual

support. This finding also alerts us to the conditions under which 12-month-olds will extend an object label. In the perceptual extension experiment described above, children were asked to extend a label after seeing a single exemplar of that object category. In this experiment, infants were exposed to three members of the category before they were asked to extend the label. This seemingly insignificant change in the experimental procedure had dramatic effects. When given just three instances of a category, 12-month-old infants readily extended to perceptually similar objects. This result is consistent with others in the literature (Balaban & Waxman, 1996).

The results from the studies on extendibility suggest that infants are conservative word learners who start only with the principle of reference and who do not readily extend a word to a category of objects, actions or events. Word extension does not come for free but may, as Golinkoff et al. (1994) and Smith (2000) argue, come about only through experience. By the beginning of the second year of life, however, children will extend words to new exemplars that share perceptual characteristics. These same children, however, will not let a social mentor guide their word extension. Indeed, it is not until 19 months of age, when most children are on the verge of the naming explosion, that infants will adopt the speaker's point of view and extend a category label to an object that does not share perceptual features with the dominant category members. It is interesting that the recruitment of social information into word learning appears at the same time for both the principles of reference and extendibility. Again, the mapping between word and referent is explained better by the associationistic theory at the outset of language development and by the social-pragmatist by the middle of the second year of life.

The patterns that emerge in the studies of reference and extendibility allow us to evaluate the original hypotheses posed by the emergentist coalition model. They also force us to reevaluate whether the different theories of word learning really offer mutually exclusive explanations of development.

Evaluating the Hypotheses

Earlier we presented three tenets of the emergentist coalition model. After our review of some of the recent research, we are now in a position to evaluate these tenets, which are after all, hypotheses about word learning.

Hypothesis 1. Is there evidence that children utilize multiple cues -- both perceptual and social -- in word learning? There is evidence from both the reference and the extendibility studies that very young word learners are using multiple cues to map words onto referents. In the study of word reference, for example, 12-month-olds, with an immature principle of reference, were already sensitive to both perceptual and social cues in the input. Though they were more heavily influenced by perceptual than social cues, they nonetheless did not mismap a word onto the more interesting object when social cues indicated that the boring toy was being labeled. Unlike their younger counterparts, 12-month-olds were aware of the social information even when they did not know how to recruit this information to attach a word to when the referent did not interest them.

Similarly, in the studies of social extension, the 12-month-olds could not rely on social cues for word learning in the absence of perceptual information. With some perceptual and social support, however, they could learn that a label could attach to a category member that shared only a salient part of the original object.

Hypothesis 2. Do the weightings of the cues shift over time? The experiments described above already give us preliminary answers to this question. For 12-month-olds, perceptual salience is dominant relative to social cues like eye gaze. For 19-month-olds, perceptual salience still predominates but social cues have gained some prominence. Finally, for the sophisticated 24-month-olds, social information can be used to override attentional cues for word learning. This pattern was apparent in both the reference and in the extendibility studies. Even when infants were sensitive to social information in our tasks, they failed to recruit this information for the purposes of word learning. This suggests that while the cues might be present for children, there is a differential reliance on these cues throughout the course of development.

Hypothesis 3. Does the child move from an immature to a mature principle of reference? The fact that older children use social cues to connect words with referents, and to extend the labels for words, suggests that these children are approaching word learning in a fundamentally different way. Young children are sensitive to a coalition of cues for word learning. Yet, they may not know which of the many cues in the coalition can be relied on. They appear not to realize that social cues are among the most reliable for word learning. The consequence of being unsure about the merit of different cues is that the learner may at first be conservative and require converging data to form word-referent connections. Children with an immature principle of reference might need to hear a novel word more times and might need to have multiple, overlapping cues for word-referent mapping than children with a mature principle of reference (Hollich et al., 2000). We discovered that when the child is “bludgeoned” by being presented with many, converging cues, the supports are sufficiently strong to allow word learning to occur.

Similarly, children with an immature principle of extendibility need to have converging data to extend a label to a like referent. In the absence of perceptual *and* social support, younger infants -- 12-month-olds -- refused to extend a label to a category member that did not closely resemble the original category items. Indeed, the youngest children -- 10-month-olds -- maintained a narrow, proper-noun assumption even when presented with perceptually equivalent items. Perhaps infant conservatism can help to explain why word learning takes place so slowly in the real world outside of the laboratory. Young children may require more support to yoke a word to its referent than they generally receive. Once they are able to weight the cues more veridically, they will require less support for word learning to occur.

Even this cursory glance at the data suggests that children with an immature principle of reference differ significantly from those with a mature principle of reference. First, these children rely more heavily on their own perspective on the word learning situation than on the speaker's perspective. They link words to referents by attending primarily to what they find interesting in the environment (perceptual salience) rather than to what the speaker is indicating. Once in possession of a more mature principle of reference, children will be able to shift their perspective to that of the speaker. When that happens, we see a fundamentally different word learner, able to serve as a socially sophisticated apprentice to the expert word learners around them. Second, immature word learners need far more support for word learning than mature word learners. Unless there are numerous cues in alignment and frequent label exposure, they will not learn new words.

There are many more studies that reinforce this shift from immature to mature learner – from more of a salience-driven learning mechanism to a socially informed mechanism (see Hollich et al., 2000). Indeed, a recent computer simulation study (Hollich, 1999) demonstrates clearly that neither associationist, nor social-pragmatic, nor constraints theories can alone explain the course of word learning. Although all three separate simulations provided a solution for how children might learn words, only the simulation that embraced the full complexity of word learning by offering multiple cues in interaction over time best fit the behavioral data.

These data suggest that a hybrid model can generate hypotheses about how different theories can be integrated into a unified theory of developmental change. With sensitive methods, a hybrid theory is empirically testable. One could argue, however, that even this description of development offers just a series of snapshots rather than a theory of developmental change. Creating a portrait of the immature and mature word learner is only the beginning of the story. The question that developmentalists must ask is *what motivates change?* What mechanisms, for example, cause the 12-month-old to abandon a focus on less reliable cues (such as perceptual salience) in favor of a focus on more reliable cues (such as social eye gaze)? Why does the child shift from needing multiple overlapping cues for word learning to single subtle social cues such as eye gaze? Such questions can only be addressed with hybrid theories and with methods like the IIPLP that permit the experimenter to focus on the interaction of multiple cues. Although we are just at the beginning of this enterprise, it seems likely that answers are more likely to emanate from complex, multifaceted theories than theories that emphasize single

mechanisms. These theories offer the opportunity to ask not just *whether* children advance from one descriptive state to another but *how* they do so.

Where Does the Emergentist Coalition Model Leave Us: Theoretical Implications

For years scientists have been trying to find the “smoking gun” in word learning theory -- endorsing one model of explanation over the others. Adopting one theory over the other however, leaves us with theories that do part, but not all, of the job of word learning. Under the emergentist coalition model, the best features of these theories are combined, in a way very different from the *either-or* theories they incorporate. This new theoretical perspective explicitly recognizes that word learning is caused by multiple cues from the outset; single factor models cannot do the job.

The implications of the case we have made is that the most parsimonious description will not come in the form of “either-or” theories that promote a single mechanism. This necessitates not only a change in our philosophy of doing research, but also a commitment to develop new methods like the IIPLP that allow for the simultaneous manipulation of multiple cues and a serious emphasis on the study of change. What have appeared to be divergent theories in our field might well be different parts of the same proverbial blind man’s elephant.

Though this paper concentrates on word learning, it could stand as a proxy for discussions ensuing in many domains within developmental psychology. From face perception (Nelson, 1999), to the perception of number (Gelman & Williams, 1998), to the perception of space (Newcombe & Huttenlocher, 2000), competing theories seem always to turn on the nature-nurture dichotomy. Yet as Elman, Bates, Johnson, Karmiloff-Smith, Parisi, and Plunkett (1996) and Nelson (1999) recently pointed out, the

brain is sculpted by experience and the emphasis on nature versus nurture is misplaced. A new concept is needed to spur the field into abandoning either-or theories and adopting theories that recognize that we live in a multivariate world where effects are caused by multiple factors. The concept of *emergentism*, with its emphasis on specifying "...in mechanistic terms the interactions between biological and environmental processes" (MacWhinney, 1999, p. x), may be the necessary antidote to this age-old and unproductive dichotomy. Emergentism seeks to account for the appearance of behaviors from the interaction of known processes without stipulating hard-wired neural circuitry.

Our version of emergentism has much in common with traditional interactionist accounts like that of Piaget (1952). However, it goes beyond interactionism since it explicitly identifies the cues that comprise the coalition that influence the emergence of new behavior and how reliance on those cues changes over developmental time. With its emphasis on how the organism essentially creates its own development, our version of emergentism also has much in common with dynamic systems theory (Thelen & Smith, 1994). Dynamic systems theory however, allows the organism to enter in an unbiased manner. Give the varied inputs available in the world, we join others in believing that some constraints or biases (whatever their source) are demanded to get developmental processes started (Gelman & Williams, 1998).

What has prevented the field from focusing on the impact of multiple inputs on development in the human organism? The zeitgeist in the philosophy of science may be at fault. Human behavior is so variable and complex that to get some purchase on it we have pared down psychological problems to their bare bones. Eager for experimental control in the laboratory, we endorse theories that allow us to cleanly manipulate at most

one or two factors. Despite the fact that statistical techniques such as the analysis of variance and hierarchical multiple regression allow for the measurement of interactions, our models are often fundamentally non-interactive and non-developmental. Truly interactive theories will isolate some description of starting points within a domain and will then ask how the behavior changes over time (Karmiloff-Smith, 1992). As in the case of word learning, competing theories may not be mutually exclusive but rather are *snapshots of behavior at different points along a developmental trajectory*.

Metaphorically, we must switch to a wide angle lens attached to a movie camera to assemble the snapshots into a developmental story that is dynamic and incorporates the multiple influences that actually impinge on human organisms. It is now time to abandon traditional views of parsimony and to generate more realistic multi-factor models of human development.

In sum, as hybrid, emergent theories become more prevalent it will be clear that nativism and environmentalism can live in peaceful co-existence (Gelman & Williams, 1998; Newcombe & Huttenlocher, 2000). The emergentist coalition model offers only one possible picture of what this co-existence might look like. Selective attention to multiple inputs preserves a place for constraints or principles models while supporting development and change in those principles over time. Principles have some foundation at the outset, but are not fully formed. They are emergent. In this emergent quality lies the potential for looking at and understanding change. If we are to understand development we must not look for a “smoking gun” explanation. Rather, we must appreciate that the answers to our questions will come from intricate theories of the ways in which children process varied inputs and the interactions among these inputs across the

developmental span. We must take seriously in the 21st century the complexity of the factors that impact on the human organism. And we must teach the next generation of developmental psychologists to do more than lip service to this notion. As MacWhinney (1999) wrote,

Students are often taught that the opposition between nativism and empiricism is the fundamental issue in developmental psychology. What they really end up learning, however, is that everything in human development depends on the interaction between nature and nurture. Unfortunately, students are given few conceptual tools to understand how this interaction occurs (p. x).

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Figure Legend

Figure 1. Principles of lexical learning (Hollich, Hirsh-Pasek, & Golinkoff, 2000)

Figure 2. Multiple cues to reference: Inputs from attentional cues, social cues and linguistic cues in a coalition model.

Figure 3. The coalition model implemented for reference. Children shift from a reliance on attentional cues like perceptual salience, to a greater dependency on social and linguistic cues.

Figure 4. The Interactive Intermodal Preferential Looking Paradigm: A hidden camera records children's looking preferences towards two objects on a display board. The mirror allows a view of the experimenter's actions, the child's visual fixation responses, and the objects on the board.