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The Change is Afoot: Emergentist Thinking in Language Acquisition

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"There is no plan. We posit that development, change, is caused by the interacting influences of heterogeneous components, each with its own take on the world. These are not encapsulated modules; indeed, development happens, behavior is fluid and adaptively intelligent because everything affects everything else. (Thelen & Smith, 1994, p. 338).

"...most everyday situations cannot be rigidly assigned to just a single script. They generally involve an interplay between a number of sources of information...each aspect of the information in the situation can act on other aspects, simultaneously influencing other aspects and being influenced by them. (McClelland, Rumelhart and Hinton, 1986 p.10)

1. INTRODUCTION

A change is afoot in cognitive psychology. The great pendulum of theory in cognitive development has cycled from Skinnerian environmentalism to Piagetian constructivism to Fodorian and Chomskian innatism. As a result, over the last three decades, much of the field has been paralyzed by debates about whether cognitive structure and process are innately constrained or are shaped

by input; whether processing is domain-specific or domain-general, whether learning is inherently constrained or associationistic in flavor (see Gleitman & Wanner, 1982; Elman, Bates, Johnson, Karmiloff-Smith, Parisi & Plunkett, 1996; Thelen & Smith, 1994). The field, however, appears amidst a kind of paradigm shift, poised to leap into an entirely new age in which many of these old debates are rendered obsolete and in which many of the old answers to our questions are being reformulated. What is this change? It is emergentist thinking: a process-oriented trend towards more fluid analyses and towards integrative approaches that do not parcel out innate from environmental influences, but rather seem to borrow the best from each of the prior theories. This view has been expressed in many areas of perception, action, and cognition (Elman et al., 1996; Karmiloff-Smith, 1992; Thelen & Smith, 1994). Some feel, however, that the final test of an emergentist theory (Elman et al., 1996) will be played out in the paradigmatic case of human intelligence: language acquisition. For as Pinker and Prince (1988) point out: "language has been the domain most demanding of articulated symbol structures governed by rules and principles and it is also the domain where such structures have been explored in the greatest depth and sophistication, within a range of theoretical frameworks and architectures" (p. 78). Thus, these theories can only be said to truly explain the range of human cognition if and only if these symbol structures can be accounted for within them.

In this chapter, we will consider how this new metatheoretical perspective impacts on language: how the introduction of concepts like downward/upward causation, emergence, and boundary conditions (Bickhard, this volume; Campbell, 1990; Kim, this volume; Emmeche, Koppe & Stjernfelt, this volume) can fundamentally redescribe the problem space in a way that provides new solutions to long debated problems and suggests a concrete plan for the direction of future research.

With this goal in mind, this paper is broken into four sections. In the first section, we will define the problem space: briefly examining the phenomenon of language acquisition, the questions to be answered, and the classic theories **that** have evolved to explain them. In the second section, we discuss the new emergentist and interactive view and how it relates to the study of language acquisition. In so doing, we briefly review three recent (and somewhat different)

incarnations of this interactive/emergentist perspective. In the third section, we demonstrate how our own work on language comprehension has benefited from the advancement in theoretical perspective, and how this perspective can speak to some of the questions raised in section one. Finally, in the fourth section, we argue that this new vantage point is more than just a redescription of old ideas: it requires a fundamental shift in the ways and means of empirical research itself.

2. A BRIEF REVIEW OF LANGUAGE ACQUISITION

By most accounts, learning a language ought to be impossible. With enormous acoustic variation between human voices and words, the complexity of our grammar, and the sheer size of our vocabularies, developing children would seem doomed to failure in their attempts to make sense of it all. Indeed, Gold (1967) argued that to induce the rules of grammar from the input would take longer than a human lifetime.

Yet, like the bumblebee who goes on flying in spite of the mathematical impossibility of such a feat, children do learn their language -- and quickly. Children utter their first words at around 12 months of age. By eighteen months of age, children's productive vocabularies increase rapidly to approximately 50 words and their development surges as they characteristically acquire, on average, 6 new words a day (Carey, 1978). Shortly thereafter, from ages two to three, grammatical growth becomes evident, going from two-word utterances to complete multi-word sentences in less than a year! By the time they are three-and-a-half years old, they are full communicative partners who have mastered the intricacies of their native tongue.

Given the ease with which children solve this learning problem and the inherent complexity of the task, it should come as no surprise that questions about language learning have been central to theories of cognitive development. That is, researchers continue to debate about how children learn to attach words to their meanings and how they learn to combine words into the regular patterns that comprise the grammar of their native tongue. Reviews of the empirical evidence on this topic have filled volumes (see Bloom, 1994). For the purpose of

this exposition, however, we restrict our discussion to the arguments surrounding the learning of grammar, for it is grammar that is considered the *sine qua non* of the language field. It is through the learning of grammar that children come to manipulate symbols in regular ways and to create the propositions that allow them to represent and communicate relations between objects, actions and events in their environment.

2.1 Learning grammar and the nature-nurture debate.

Grammar is composed of a set of linguistic units and of the relations that adhere among these units. Grammatical units come in a number of forms from nouns (e.g. cats and dogs), noun phrases (e.g. "The cats" or "the beautiful dogs"), clauses (e.g. "The cats were found with the beautiful dogs") and even combinations of clauses (e.g. "The cats were found with the beautiful dogs and the frogs were found with the ducks."), to units like subjects and direct objects, among others. To learn the grammar of a language, children must discover both these units (**e.g.,** Find the unit within the acoustic flux) and identify them (e.g., This is a noun). Unfortunately, linguistic units are not well-marked in the input stream. They are not punctuated for the learner with spaces, periods and commas. As anyone visiting a foreign country can attest, it is quite difficult to find the beginnings and ends of words if one does not already know the language. Thus, even the discovery of the language units is a most challenging task for the learner!

This discovery and identification of the units is even more difficult when we realize that units like nouns and noun phrases, verbs and verb phrases, (among others) bear a hierarchical relationship to one another such that nouns can and do occur in noun phrases which themselves occur in clauses (hierarchical embedding). Therefore, no simple *Markovian* (word by word) analysis will allow the children to discover or identify the many different units of language. The unit problem, therefore, exposes some of the complexity of what must be learned in

language development and speaks to the kinds of processes that must be explained by any adequate theory.

Not only does the learner face the problem of finding and identifying the units of language, but also of noting the relationships that hold among units like noun phrases and verb phrases. Unit relations refer to the ways in which the units pattern to allow for some understanding of "who is doing what to whom." One relation that is often discussed is that of word order. For example, Steven Pinker (1994) eloquently points out that in the sentence, "man bites dog," it's not enough to know that men, dogs, and biting are involved. One must pay attention to word order in order to determine whether the sentence is big news or nothing special. English is a language heavily reliant on word order relations. Other languages like Imbabura Quechuan use inflectional marking to indicate the role of a unit within the language and hence dispense with word order cues almost entirely. By way of example, The English sentence, "You saw me" would be rendered as riku-wa rka-nki (literally as, "see, first person object past second person subject"). Speakers in non-word-order languages learn to paste together affixes, to specify the grammatical roles that the words play.

The use of different rules raises the stakes considerably. Not only must the naive learner discover what those rules are, but the learning system must be flexible enough to learn any of the grammatical relations that might be encountered in the environment. Babies cannot know, a priori, what language they will have to learn. Another, perhaps more problematic fact for the learner is that these rules -- like the units over which they are realized -- are not transparently represented in the input. Language relations are structurally or context dependent (e.g., structure dependency). This requires any reasonable theory of language learning to specify both the units and the ways children might attend to those units and their relations in ongoing speech. An example of structural dependency can be found in the formation of the question rule or relation from the simple declarative sentence. The question, "Will John come?" might lead the child to suspect that question formation is achieved by inverting the first two words in a sentence. This simple rule quickly fails, however, when he sees the corollary question, "Will John's sister come?" ("*John's will sister come.") and becomes even more apparent when the child is faced with questions

derived from more than one clause: "Will the man who will come be John?" (which "will" do we use?). To solve the latter problem, children must know that the "will" to be fronted is from the main clause.

The logical problem of language acquisition, therefore, is that children are virtual experts at using language by three-and-a-half years even though languages vary on certain critical grammatical parameters; even though the input seems to be impoverished (in that it offers no transparent solutions to finding unit hierarchies and structural dependent relations); and even though parents rarely if ever correct their children when they make utter incorrect grammatical utterances (as in "I goes to the store," see for example Bohannon & Stanowitz, 1988; Pinker, 1989). How can theorists explain children's remarkable success? They do so through appeal to either constraint theories (that are largely *nature*) or constructivist theories (that support a larger role for *nurture*).

2.2 Nature versus Nurture/Constructivist theories.

Though we are about to embark on a quick review of these nature or nurture approaches, it is important to stress at the outset that there is no pure form of either position. Each class of theorists needs the other to explain language acquisition in total. Thus, the difference among the theories is more one of degree or emphasis than of kind. For those heavily weighted towards a nature account, nurture serves the role of triggering the internal grammatical system in highly constrained ways. Those who favor nurture explanations must come to explain how children direct attention to some aspects of the environment over others thereby relying on some types of information as relevant to the task at hand while ignoring other types of information as irrelevant to the task. To say, for example, that children attend to certain rhythms in the speech stream or to certain types of acoustic information over others is to say that at least some predispositions exist for language learning, while recognizing that these are not, strictly speaking, linguistic abilities.

Despite the lack of pure cases, nature and nurture explanations have defined the theoretical playing field for explanations of grammatical development. These positions are reflected in various guises. Those endorsing the nature position tend to support domain-specific hypotheses in which the structures and processes that read input are specific to the processing of language stimuli. The nature theorists generally endorse a constraints view of learning in which boundary conditions or biological predispositions are set that delimit the kinds of input that are relevant and the ways in which the units can be arranged into various relations. Nature theories often, though not always, support a modular interpretation in which language is served by specialized, encapsulated neurological architecture that is unable to draw inferences from non-language inputs (Fodor, 1983; Chomsky 1986). This view is characterized by Hirsh-Pasek and Golinkoff (1996) as the "inside out" view of language development, in which pre-formed representations and structures must be linked to the outside input and are then fully realized as language units and relations within the native tongue.

In stark contrast to this view is the "outside-in" camp of theorists. Again, this camp represents an eclectic group (Schlesinger, 1982, Bates, 1979; Bates, Bretherton, & Snyder, 1988; MacNamara, 1982). Generally, however, this group endorses domain general learning and writes of non-modular learning mechanisms that are served by multiple sources of input. In many cases, the "outside-in" group also supports a constructivist approach to the language learning problem. Heralded by researchers like Bates & MacWhinney (1989), Braine (1976), Piaget, (1952), Schlesinger, (1988) and Greenfield (1991) among others, this approach suggests that language is like other cognitive skills, and should be readily mapped onto existing cognitive structures and processes. Language structure, then, is constructed by the child, either in the context of pragmatically elaborate communicative contexts (e.g., Snow, 1986; Nelson, 1974, 1985) or as an extension of conceptual understanding, which is the logical precursor to language (e.g., Bates & MacWhinney, 1989). These researchers tend to designate primary explanatory prominence to the highly structured linguistic environment, rich in complex systems of grammatical, semantic and phonological patterns that bombard the young learner from the outset of life (Snow, 1986; Bates & MacWhinney, 1987). Thus, parents tend to highlight language units like

noun phrases by using them at the ends of sentences, by giving them extra stress, and by repeating them more often. Parents also draw infants' attention to language by using a specialized speech register, termed child- or infant-directed speech (Fernald, 1991). The savvy infant who can read social cues and who is in a conversationally eliciting environment, can learn language units and rules by attending to social and functional cues as well as by computing statistical regularities in the use of these units (Nelson, 1985; Schlesinger, 1988; Snow, 1986) Rather than defaulting to an innately-specified language acquisition device (Chomsky, 1965; Lightfoot, 1989), the outside-in theories offer a position in which social partners compensate for the poverty of the input.

To date, each camp has its supporters. Yet, evidence in favor of nativistic explanations for language development has tended to rule the day (Bickerton, 1984; Chomsky, 1986; Lightfoot, 1989; Pinker, 1994; Gleitman, 1981). Much research suggests that language development does not tend to follow the path of general cognitive development -- and hence is not governed by domain general rules. By way of example, it has been demonstrated that children with severe cognitive impairments nonetheless develop normal grammatical performance (e.g., Curtiss, 1977). If general cognitive devices were responsible for language (**e.g.,** language was not unique) there should be a tight isomorphy between language and other cognitions and language development should not diverge from general cognitive development.

Evidence also suggests that children in all cultures learn language at about the same rate, and reach more or less similar levels of competence, regardless of the richness in their learning environments (see also Bickerton, 1984). Even deaf children of hearing parents who have little linguistic input tend to create a language (home sign) that has many of the grammatical properties evident in the language of children who receive a much richer language input (Goldin-Meadows & Mylander, 1984). That is, these children seem to derive hierarchical relations and structural dependency despite their limited input.

Finally, the fact that there are critical periods for language learning before which children can master new grammars and after which it is exceedingly difficult to learn these grammars is also used to buttress nativist claims (Johnson & Newport, 1991; Lenneberg, 1967). These are just of few of the many arguments

that nativists raise in support of the "language instinct" (Pinker, 1994), in support for the nature view of language development over the nurture view.

In short, while there is ample evidence that the environment does affect language development, especially vocabulary development (Tomasello, 1986), and to some extent grammar (Nelson, 1988), the social constructivist theories have yet to offer compelling explanations of how the child becomes a sophisticated speaker of her native language by age three or four. These theories still cannot offer a full or sufficient explanation of how it is that children can say multiply embedded sentences like, "The man the girl kissed fled." These theories still have problems in articulating how children come to discover and identify the units of language and the relations among them. Thus, after almost 30 years of debate, the nativistic position continues to dominate the field, mostly by way of default (it is argued that if it cannot be explained any other way, it must be a product of nature).[1] The burden of proof is on the social constructivists to address the logical problem of language acquisition and to show that domain general architectures can account for the timing and agility of the language learning process. It is at this point in history -- with two seemingly incompatible theories in hand, that the new wave of thinking will make its mark by

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[1] Bickhard (1995) argues convincingly that the traditional innatist account of language acquisition, and the field's tendency to "default" to reliance on innate *grammatical* constraints is based on a false assumption about the arbitrary nature of these structures, and the underspecification of these structures from the linguistic environment (the "poverty of the stimulus" argument). By contrast, Bickhard shows that key principles of linguistic structure, the UG, can be theoretically derived as *logical* constraints on any representational system that functions in the way language does: "This (innatist) argument presupposes that experience and genes exhaust the possible sources of constraint on language and language learning " (1995, p. 548). By adopting a functional account to explain linguistic constraints, showing how relationally structured representations can give rise to propositionally structured utterances, Bickhard's formulation permits the possibility that the so-called innate component in language development is actually *emergent* over developmental time through the refinement of a sophisticated relational-representational system.

demonstrating that these two diametrically opposed ways of addressing the puzzles of language acquisition are not incompatible. What the new wave of theorizing in the field of cognitive development helps illuminate is that grammatical acquisition is the product both of innate constraints and socio-environmental inputs. In the newer theories, we begin to see that the nature-nurture debate has played a polarizing role in our conception of how cognitive processes develop. This debate crystallized some of the differences (rather than the similarities) between the major theories and created a situation in which scientists felt bound to one camp or the other with apparently no hope of reconciliation.

3 THE "NEW WAVE"

Given the twin facts that the field of language development has been polarized by a potentially false dichotomy and that parts of each of the theories mentioned can account for a substantial amount of the variance in language acquisition, it is time for a reconciliation. We agree with those who suggest it is time to "rethink innateness" (Elman et al., 1996), to break the conceptual paralysis that has gripped the field, to pose a reformulation of the entire nature-nurture question, and indeed, to reformulate cognitive developmental theory in general. In this new formulation, the question of "where" language structure "exists" before it is realized in development has given way to a set of entirely different questions, questions like: Under what conditions and under what constraints (either domain-specific or domain-general) does the child construct language? Are there multiple inputs to emergent word and grammatical systems? Most importantly, what is the process by which these inputs interact to create complex systems?

As we will demonstrate, the different instantiations of this new wave of thinking represent divergent points of view within cognitive developmental psychology. Despite their differences, however, all of these newer theories share the dominant theme that it is no longer profitable to be caught on the horns of the

nature/ nurture debate. In the next section, we will consider this 'new wave' of thinking and the ways in which it is changing research in language development.

3.1 Emergence of the "New Wave."

3.1.1 Historical beginnings.

This new thinking within the field of cognitive psychology starts as all good ideas do, not by reinventing the wheel, but by at least recognizing its elegance and its place in the history of the domain. In this case, the old wheel is "interactionism." It has been suggested recently that the term, because of its heavy baggage and history, has been voided of any universal meaning (Oyama, 1985). In one way or another, everyone is to some extent an interactionist. Chomsky and his nativist followers are interactionists in the sense that all children must interact with the input to discover the grammar of their native tongue. The social pragmatists are interactionists in that it is through interaction with a socially sophisticated linguistic partner that we are guided in the construction of language. Indeed, interactionism is not only a loaded term, but is a term that is not operationally well-defined within the field.

Of interest for us here, however, is the current speculative notion that true interactionism is "emergentism." That is, if we wish to discuss a domain like language, questions that start "Where does structure X come from" should be given only passing attention. Several theorists have recognized that a developmental explanation of such a complex system cannot rely on the 'smoking guns' of genes or environment for much longer. We must instead consider a more flexible and temporally variable array of input sources, some of which are more heavily available early in the process, like acoustics, and some which come into play much later in the language game, like semantics or syntax. (Nelson, 1996)

Thus, at a time when the field of cognitive psychology is coming to stress the importance of interactionism and studying systems as dynamic entities, psychologists are becoming aware that mathematical theories to describe these phenomena already exist. These theories have many faces, and have been alternately called dynamic systems theory, developmental systems theory, success-driven learning theory, distributional learning theory, nonlinear dynamic theory, or chaos theory: to name a few. Whatever the name, they share three common themes: 1) Simple regularities when iterated can produce extraordinarily varied and complex behavior that is emergent from the interaction at the lower levels (upward causation). 2) Each problem space has its own set of constraints or boundary conditions which serve to limit the behavior of the system and which can produce discontinuous patterns of behavior, or phase shifts, from a single nonlinear process. 3) Finally, there is a beginning realization that, often the emergent whole may affect the lower levels as well: downward causation.

3.2 Three recent instantiations of the "new wave."

In the past five years, there has been a proliferation of these dynamically-flavored theories within cognitive development. In this section, we present a cursory review of three such instantiations. We will then use these three as a base from which to further elaborate on the central themes of the new wave outlined above. As with any cursory review, we will of necessity simplify and gloss over what are major differences in an effort to highlight what has changed. Let us apologize at the outset for any injustice that will be done here. After reviewing and extracting these common themes, we illustrate one use of the new trend in Hirsh-Pasek and Golinkoff's (1996) coalition models of grammatical and word learning.

3.2.1 Thelen and Smith: The Dynamic Systems Perspective

Thelen and Smith (1994; Smith & Thelen, 1993) were among the first to import chaos theory and systems theory into the field of cognitive psychology (see also Thelen 1989, Oyama, 1985). In contrast to many of the theories we have already examined, the hallmarks of dynamic thinking are attention to process rather than to structure. The dynamic theorist is less concerned with looking for sources of static, unchanging structure, either in the environment or in the 'head' of the individual. Instead, this view proposes that structure is dependent on process. Through a highly contingent, multiply-caused and multiply informed constructive interplay of organism and context, systems emerge in developmental time.

Thelen and Smith demonstrate this theory by considering the problem of learning to walk: "locomotor development in cats, as well as in frogs, chicks, and humans, is [made up of many components] and context sensitive. Cats can generate patterned limb activity very early in life, but walking alone requires more -- postural stability, strong muscles and bones, motivation to move forward, a facilitative state of arousal, and an appropriate substrate. Only when these components act together does the cat truly walk" (p. 20).

One attractive feature of this perspective is that it defuses some of the conflict between the either-or views of environmental and innatist theories. Language is not 'learned' in any traditional sense, where learning means a transparent mapping of environmentally-given information. Likewise, language does not simply evolve out of biological, programmatic instructions. Instead, this view allows that multiple sources of information (both in the input and in the biological prerequisites) compel the process in a nonlinear, non-additive fashion. This thereby combines aspects of both nativist and constructivist theories.

In the same sense, language development can be seen as being composed of many different components. It is only when words, grammar, social-interaction, environmental cues and a biologically appropriate substrate "act together" that the child can be said to "truly" construct grammar, in the fullest sense. Thus, the study of language, and indeed, any developmental phenomenon, for Thelen and Smith, involves a consideration of the dynamic interaction of multiple factors: both biological and socio-environmental. (See Tucker & Hirsh-

Pasek, 1993, for a fuller treatment of the way in which these ideas can account for phonological and grammatical development as well as Hirsh-Pasek, Tucker & Golinkoff, 1995; Hirsh-Pasek & Golinkoff, 1996.)

A theoretical perspective with attention to the dynamic interaction of multiple factors has led to some interesting caveats. First, although the precise evolution of any system may be unpredictable, the interaction will almost always conform to some kind of pattern, or attractor, for behavior. For example, although one might have trouble predicting the exact path a boulder might take when rolling down a mountain, one could quite accurately predict the stable end state (the bottom). Moreover, one could mathematically induce the kinds of forces necessary to produce a general path and end state: even to the point of modeling the system on a computer. Indeed, one of the great advantages of such an approach is to be able to predict qualitative behaviors of dynamic systems. That is, we can predict the kinds of things such a system can and can not do, the paths of language development that a child can and cannot take.

Second, many systems even have more than one possible attractor, or stable solution. Thus, a fertilized egg could become either a boy or a girl depending on the interaction between the genetic sequence and its intercellular environment. Likewise, French, German, and Italian all represent stable solutions to the language problem, with each seeming to work equally well for their practitioners.[2]

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[2] Campbell (1990) provides a similar example in recognizing the conributions of upward and downward causation, of macro- and microdeterminants of form, in the formation of the jaws of the soldier ant. These creatures serve a single purpose in the social order of the ant: their jaws are specially designed to pierce other organisms. So, in one sense the genetics of the ant (and Archimedes' laws of levers) selects functional pincer forms over others. This would be an incomplete picture, however, since we must also appeal to the sociological laws of "division-of-labor social organization" to explain why some ants are only food-gatherers, while others like the soldier ant, are utilized only for defense. Retreating to either the sociological or the biological (or, indeed, the mechanical) in explaining a) the role of the soldier ant in a colony's sociology and b) the shape of its unique mandles greatly oversimplifies the issue

Finally, some solutions are better than others depending on the functional context. This can lead to sometimes sudden phase shifts in behavior. So children who initially use their fingers to count might suddenly shift to rote remembering, and a person who wants to get somewhere quickly might suddenly shift from fast walking into running. In the language domain, children who might differentially rely on semantic cues at one age may come to rely on syntactic or grammatical cues at a more advanced level. By way of example, the child who hears the sentence, "Baby feeds mommy" might assume that mommy is feeding the baby because semantic and pragmatic cues dictate that interpretation despite the grammatical cues. The sophisticated toddler of three or four, however, lets the grammatical information dictate the interpretation.

According to Thelen and Smith, development -- language or otherwise -- is the evolution of a system, from an initially unstable starting point to higher and higher levels of organization, successive stable attractors. The study of development, then, is the induction of the processes and boundary conditions which serve to produce the patterns of behavior (attractors) seen.

3.2.2 Karmiloff-Smith: Representational Redescription.

Thelen and Smith (1994) speak of interactionism in terms of dynamic systems theory. For Karmiloff-Smith (1992), the neuvo interactionism is codified through representational redescription. Her theory was motivated by the need to shift one of the staples in interactionism, a focus on failure-driven learning (Piaget, 1955). A most outspoken interactionist in the truest sense, Piaget argued that qualitative shifts in forms of thought arose through discrepancies between an existing structural organization and some environmental condition. Children may have mental structures that do not allow them to see that two beakers of water of different shape contained the same amount of liquid. In order for the child to reconcile this apparent contradiction in between their mental structure and the world, something had to change. In most cases, the change that occurred was

within the child; more formally, the mental structures contributing to notions of conservation were modified to accommodate this new understanding. In this way, old forms of thinking gave way to new in a continuous process of equilibration, or movement from lower to higher forms of mental coordination. Qualitative, adaptive changes in thought take place when discrepancies between the expected and the manifest engender a cascading structural reorganization, a change in the child's representations of the problem and its solutions.

Karmiloff-Smith suggests that failure-driven models of learning ignore important developmental changes that occur when a given cognitive system is procedurally successful. Karmiloff-Smith's alternative is the model of representational redescription (the RR model hereafter; Karmiloff-Smith 1992). This model consists of four levels of representation, each of which arises through the redescription, or re-encoding, of the prior level. At each successive level, these representations become more explicit and hence more available to linguistic expression. Thus, Development proceeds from implicit representations of basic behavioral procedures to successively more abstract, explicit, and flexible structures. Through this developmental process, representations become successively more adaptive, enabling the organism to enhance interaction with the environment, without appealing to failure of previous engagements.

Karmiloff-Smith's model provides a mechanism, albeit a speculative one, by which representational change occurs developmentally without appeals to failure, and remains faithful to an emergentist approach emphasizing domain- specific constraints (or boundary conditions) on development that are decidedly non-modular. Children need not come to the task with a finely tuned storehouse of language-relevant representations to explain what they eventually acquire. Finally, the RR model attempts to explain the emergence of domain-specific representations that are explicit and amenable to linguistic description through the representational redescription of implicit perceptual or motor procedures.

It may be useful to consider the RR model a sort of 'constrained constructivism.' Karmiloff-Smith remains essentially true to a constructive epistemology, arguing that we need not attribute sophistication to our naive learners in order to explain how they know what they know. Language, like other domains of knowledge, may capitalize on innate perceptual biases (e.g.,

constraints on attention) that lead the child to focus strongly on some input classes while virtually ignoring others. So, we might speculate that the child will find human speech, and child-directed speech in particular, more interesting than the sounds of cars moving outside the home, or the random noises made by household appliances. This places the RR model, and the specific formulations of micro-domains within language, at a place midway between and slightly above the old nature-nurture dichotomy. However, it is important to recognize (as others have, Bickhard, 1995) that while Karmiloff-Smith apparently rejects the old nature-nurture dichotomy in toto, the fact remains that her model does not completely eradicate the old idea. For example, it is still, in this developmental approach, we find that the tired question of **where** information comes from is still answered by the age-old answer, one still clinging to a limited albeit more interactionist set of developmental propositions. In her formulations, Karmiloff-Smith fails to embrace an emergentist approach of the sort advocated elsewhere in this volume. That is, in asking the question of **where** the information derives, Karmiloff-Smith closes off the alternative possibility that the question is based on a false premise and a fruitless reliance on a strict deterministic (or temporally and logically "upward causation") answer (see Bickhard, 1995).

One particularly attractive feature of the RR view is that it allows for domain-specific learning that is not initially modular. Modularity may be the product of development, not its cause. In particular, Karmiloff-Smith argues that building in such fine-tuned and highly specified representations prior to language learning makes the system too rigid to account for variability in language use among children: "*The more complex the picture we ultimately build of the innate capacities of the infant mind, the more important it becomes for us to explain the flexibility of subsequent cognitive development*" (1992, p. 9, emphasis in original).

What does the RR model offer? First, it makes a useful distinction between procedural knowledge at the behavioral level and representational knowledge that later becomes amenable to linguistic expression. Karmiloff-Smith argues that behavioral mastery of a domain (say, mastering the articulatory gestures involved in producing understandable speech sounds) is the first step in internalizing knowledge about such behavior. Second, this theory provides a putative

mechanism (the "system-internal dynamics") by which initially implicit procedural representations become available outside of the initial domain through redescription into more abstract symbolic forms.

Additionally, Karmiloff-Smith herself has recently "redescribed" certain aspects of this approach, and it is to this more current instantiation of these ideas we turn in the next section (Elman et al., 1996). However, we should emphasize again the relevance of this view for our central argument here. In this RR model, appeals to domain-specific structures or representations are rejected in favor of biases or perceptual constraints. Incidentally, this idea has become popular in other conceptualizations of language acquisition as well (Jusczyk & Bertoncini, 1988; Hirsh-Pasek & Golinkoff, 1996; Tucker & Hirsh-Pasek, 1993). Over time, these initial predispositions may indeed become more insulated and modular in character (a process referred to as emergent modularity, Greenfield, 1991, Karmiloff-Smith, 1992, Tucker & Hirsh-Pasek, 1993). Importantly, they did not start out that way, and it is this critical factor that makes emergentist views so distinct from traditional nativist accounts.

3.2.3 Elman, et. al: Rethinking Innateness

"... we argue that some innate predispositions -- architectural, chronotropic and, rarely, representational -- channel the infant's attention to certain aspects of the environment over others. Our view is that these predispositions play different roles at different levels, and that as far as representation-specific predispositions are concerned, they may only be specified at the subcortical level as little more than attention grabbers so that the organism ensures itself of massive experience of certain inputs prior to subsequent learning." (Elman et al., 1996, p. 108).

In this last and current instantiation of interactionism, we see the most recent of Karmiloff-Smith's perspective as it melds with what has been called 'new age' connectionism. Connectionism is a way of modeling computer learning in ways thought to be compatible with the activity and structure of the human brain. A connectionist (or parallel distributed processing) network

generally contains three layers of units called nodes. The inputs consist of one layer, outputs another, and in between these is a layer of so-called hidden units in which processing takes place. Processing in a network like this takes the form of activation of nodes from input, through the hidden units, to output. Changes in the activity of the net are achieved by altering the weights among connections, and these modifications are achieved either directly by the modeler, or through experience, via the inputs the network receives. "Learning" in a network, then, is operationalized as modifications of the node connections in response to cascading waves of input sequences (epochs) that impinge the input layer.

Connectionist nets show themselves very flexible learning engines. Indeed, networks have attempted to learn everything from English phonology to the differences between regular and irregular verbs. Through tutoring and error-correcting (binary right-wrong distinctions) complex behavior "emerges" from the network.

The network differs from traditional algorithmic programming in several respects. First, nowhere in the network are propositional representations of the things it "knows": in the most sophisticated networks, say, for learning English verb morphology, there are no verb nodes, or regular and irregular nodes. These features emerge out of the activity of the whole network, based on the network's training history and present sources of input. The "solutions [are] contained in the structure of the problem space" (Elman et al., 1996). This problem space includes the network itself, its architecture, its history, and the context of inputs and outputs it is receiving and producing, respectively.

Finally, and perhaps most important considering our early discussions of constraints, the net has no innate preprogrammed structure beyond the architecture described above. The weights merely represent "attentional constraints" in the broadest sense of the term. The system simply begins with a bias to attend to certain aspects of the input over others, as we saw in Karmiloff-Smith's earlier model. By limiting the source of information in these initial ways (a "sensitive dependence on initial conditions," Gleick, 1987), the complexity of subsequent behavior falls out of the activity of the network.

There are other facets of this modeling technique that we will ignore for the present. Instead, let us consider what Elman et al. (1996) have asserted, based

on these facts about connectionist architecture, and what implications these ideas might have for an emergentist program.

First, as their title suggests, ideas about innateness fundamentally change. Indeed, Elman et al. (1996) suggest that innateness takes place on several levels, including the architecture of cells in the brain, the arrangement of neurons in cortical and subcortical patterns, and so forth. Other aspects of innate constraints can include: innate representations,[3] innate mechanism or procedures, and constraints in developmental timing.

Second, we are no longer theorizing with one hand tied behind our backs. That is, the old formulations about nativism and constructivism allowed only either-or dichotomies, nature or nurture. Here we see how one can incorporate biases (or principles, or constraints) into one's model of development without adopting strong preformationist-style innatism. The biases begin the process. Attention to some kinds of information is stronger at the outset. These biases, however, do not constitute knowledge in an abstract or explicit sense, and simply start the ball rolling.

Third, it is certainly the case that many different patterns of development may lead to similar outcomes, but these outcomes (solutions to the problem) are not uniform in any strict sense. Here we see again the attractiveness of ideas about individual differences and complexity. Uniformity on one level gives way, with more refined focus, to dynamic differences in performance, competence, and representations.

Fourth and finally, modeling of a connectionist sort leads to the supposition that qualitative changes at the behavioral level need not be governed by qualitative changes at the representational level. This final point is perhaps most controversial to those coming from a more traditional constructivist background, since many theorists, including ourselves, suggest that fundamental

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[3] The possibility of innate representation is a proposition that Elman et al. (1996) argue is least likely, but which has been advocated extensively by structural-innatists like Chomsky (1965) or Fodor (1983).

changes in representational capacity are necessary to explain cognitive advances.[4]

Applying these ideas to the language arena, we see that Elman et al's (1996) position mirrors much of what we saw in both Thelen and Smith's and Karmiloff-Smith's accounts of learning. Cognitive behaviors are emergent from rather scant beginnings that help the system focus on domain relevant stimuli in the environment. In each account, the system is sensitive to multiple inputs from numerous sources (e.g. from social inputs and biological inputs). In each account, the line between the contributions of nature and nurture is blurred if not obliterated. In each account, emergent behaviors are governed simultaneously by upward causation, downward causation and boundary conditions. Taken in combination, these three theories allow for a fresh look at specific behavior like language development and allow us to re-frame many of the old questions that had so dominated the field.

3.3 Riding the "new wave" in language.

As we look at the three theories discussed above with a broad stroke, we see some commonalties that incorporate themes of upward causation, boundary conditions, and downward causation. Indeed, these new trends seem to forecast a number of central assumptions that could fundamentally change both the study of cognition and the field of language acquisition. It is thus worth exploring how each of the three themes of emergentist thinking impact upon the picture of language development that was sketched earlier.

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[4] Indeed, our extended discussion of the implications of a connectionist architecture solution to the nature-nurture dilemma should not be misunderstood as an endorsement of a connectionist model of human cognition. While neural nets provide an interesting aproach to modeling cognition, it does not logically follow that they accurately reflect the processes and representations involved in real-time human cognition, and they fall well short of providing a detailed explanation of language use or acquisition.

3.3.1 Upward Causation

The first change in thinking reflected in the above theories is the growing recognition that answers to questions about the sources of linguistic structure ("Where does grammar come from?") are not going to be found in transparent accounts of external sources ("From the grammar that you heard when your parents spoke to you") or from the promise of biologically-determined language organs in the brain ("From the maturation of innate linguistic stuff"). Instead, there is been a renewed interest in structure that emerges with time, and is not reducible to early structure or to static processes that can be observed environmentally. This more process-oriented theorizing has shifted the focus of attention from "Where"-type questions to "How"- type questions, and leads us to expect that emergence, truly considered, may provide many of those answers. Thus, upward causation becomes central to theories of development.

In the field of language development, this emergentism also seems to be couched in a distributional learning model. Children are seen as miniature statisticians noting distributional and statistical regularities among many input sources to determine the characteristics of words or of grammatical properties (e.g., Saffran, Aslin & Newport, 1996; Saffran, Newport, & Aslin, 1996). So, for example, Golinkoff and Hirsh-Pasek (1996) suggest that infants may use a form of guided distributional learning to find classes of words like 'nouns' in the input stream. Scanning for evidence of heavy prosodic stress and sentence position, children might be able to use minimal structural and acoustic cues to construct a grammatical category, from the bottom-up.

3.3.2 Boundary Conditions and Phase Shifts

The new perspective also supports a view of constraints or boundary conditions. Innate predispositions must be in place for the child to even extract the relevant information from the input (e.g., Elman et al., 1996; Karmiloff-Smith**,** 1992; Jusczyk, 1997). The infant listener is constrained to focus on certain human speech patterns and to ignore others as irrelevant for meaning.

By way of example, it has been argued that we hear 17 different acoustic sounds in every syllable of speech. Luckily, we do not attend to all of these acoustic variations when we want to extract meaning from the speech stream. In fact, we ignore large differences between a male and female voice both uttering the word 'stop,' but closely attend to seemingly small differences in the words 'stop' and 'spot.' If we postulate an unconstrained learner, randomly analyzing the input, language would quickly become impossible. Yet, the theories proposed above all propose a learner who is predisposed to focus on certain properties of the input over others.

It is important to note that in the new wave of thinking, boundary conditions do not restrict the learner to one universal solution to a cognitive problem, but merely assist in defining a set of more or less probabilistic solutions to that problem. Hence, constraints need not be universals that permit no variability. This view allows researchers to see not only the universal properties of language development that all children share, but also the variability that characterizes both individual development and language change (see Bates, Bretherton & Snyder, 1988) all within a unified theoretical paradigm.

3.3.3 Downward Causation.

Explicit reference to downward causation in language development is uncommon, although the ideas represented elsewhere in this volume are suggestive of the kinds of dichotomies we elaborated in previous sections. The either-or approach, the false dichotomy of development, is central to any mechanistic enterprise, and this reliance on a mechanistic research program (an efficient Aristotelian causality) pervades much of developmental thought.

Stripped to its essentials, the approach is an attempt to either avoid the recognition of emergence (formal and final causality) or to *reduce* it to the level of epiphenomenon, vacuous or at best, uninteresting (see also Overton, 1991). In their criticism of Klee's microdeterminism , Moreno and Umerez (this volume) highlight exactly the points the emergentist theories we advocate as plausible for the domain of language. The preformationist view of development in language mirrors the discussion seen in other domains, especially in developmental biology. Indeed, one fundamental tenet of the strongest innatist approaches has been that at its core, language development is a *biological*, rather than a psychological phenomenon.

Although downward causation models have not been as well-represented in the language-learning literature as have constraint or emergence models, downward causation might indeed play a critical role in theories of language in at least two ways: what we will refer to as internal downward causation and external downward causation. By internal downward causation, we refer to the idea that emergent properties of the system become self-organized at higher levels which themselves come to redescribe or constrain further processing (a medium-causation view, see Emmeche, Koppe and Stjernfelt, this volume). So, for example, each of the three theories presented above suggests emergent modularity is a likely property of developmental systems. Once a child's cognitive system, becomes modularized, it is likely that they will begin to process relevant input in different ways. By way of example, there is evidence in the area of developing phonology (the sounds of language) that children begin to process speech with an ear to all languages -- readily distinguishing phonemes in Hindi, Japanese and English. Over time, however, the system becomes more specialized and seems less able to note those same distinctions in other languages when they are presented (Best, McRoberts & Sithole, 1988; Werker & Tees, 1984). Thus, the Japanese eight-month-old might hear the distinction between /r/ and /l/ that an older child finds more difficult to detect.

By external downward causation, we refer to outside influences from an organized system that directs lower level processing. Thus, the social interactionists could be said to represent downward-causationists in that sophisticated social partners impose order on the incoming stimuli that helps the

child narrow the field of candidates for particular linguistic units. In word learning, for example, caretaker eye-gaze can direct the learner to expect words to have some meanings over others. If Mom is looking at a picture of an unknown animal in a book, the child may expect that when she utters 'aardvark' she is not referring to other objects in the room like the telephone or the pencil sharpener (Tomasello & Kruger, 1992)

Social inputs can also assist children in learning the differences in literal and metaphorical language. Thus, while initial interpretation of the sentence: 'it's raining cats and dogs,' might be quite literal, subsequent experience with the language in a social scene might lead to a more metaphorical interpretation. As Asch and Nerlove, (1960) show, children seem to progress through stages of metaphor interpretation: initially being quite literal and only later able to routinely assign abstract meanings to new metaphors. Thus, growing and emergent abstract knowledge about the workings of language serve to constrain subsequent interpretation.

3.3.4 Putting it all together.

Thelen and Smith's dynamic systems theory, Karmiloff-Smith's representational redescription and Elman et al's connectionist approach are recent models that represent dramatic changes within cognitive developmental psychology over the last five years. While they are theoretically distinct, it is our opinion that they have the potential to change the landscape in cognitive development by stressing several characteristic themes. The first is that the nature/nurture debate tends to dissolve, giving way to discussions of emergent behavior built upon distributional evidence. The second theme is boundary conditions can and probably do exist either in the global architecture of the system or in the structure of the representation within the system. The third theme is that more complex systems can serve to drive the developing system and can provide yet another signpost for development through downward causation. None of these positions is really new. It could be argued that each of the warring

factions (Chomsky vs. Piagetian alternatives) that traditionally characterized theories of language development can comfortably sit within one of these camps. What makes the new perspective really new, however, is that researchers of tomorrow will not have to choose from among these alternatives, but can begin to see these as mutually compatible and necessary explanations for complex behaviors like language development. This brings us to the final and perhaps most central point about the new wave. The real change in cognition and language development comes in the form of increased attention to multiple and mutually reinforcing sources of linguistic information that act in concert to ensure development. Each of the three representative theories above speak to this issue. Cognition will not and cannot be explained through appeal to exclusive reliance on either upward or downward causation or through boundary conditions. Single cause theories are too restrictive, are unnecessarily confining and are incapable of explaining the complexity of the various cognitive systems in a unified way. It is when we look instead to multiple sources of information: to a coalition of cues (Hirsh-Pasek & Golinkoff, 1996) that work in concert across developmental time that we begin to allow for the emergence and construction of word learning and grammatical development.

3.4   The 'new wave' in our research: Hirsh-Pasek and Golinkoff's Coalition Government Model of Language Comprehension.

Hirsh-Pasek and Golinkoff's (1996) 'coalition model' embodies many of the characteristics of the newer theories. Though it represents a work-in-progress, we use it here to illustrate how ideas like emergence, phase shifts and boundary conditions can be profitably incorporated into a model of language development and how the resulting theories can be used to address the logical problem of language acquisition.

The coalition model embraces several key assumptions. First, Golinkoff and Hirsh-Pasek suggest that language comprehension is an emergent property of a complex system. That is, children begin to comprehend language when they

compute the earliest relationships between inputs like sights and sounds in a very general and shallow way. This initial analysis of the input allows children to internalize chunks of sound (or visual input in the case of sign language) that will be language relevant and that will eventually serve as cues to the more sophisticated and abstract grammatical units of language.

Second, the model holds that children are confronted with a 'coalition' of inputs that are always available and highly redundant with one another. To learn the grammar of their language -- to comprehend the language around them, children must mine the coalition of input cues.

Third, children are predisposed (boundary conditions) to attend to certain cues over others in each of the input arenas. Through what Hirsh-Pasek and Golinkoff (1996) call 'guided distributional learning' children are thought to attend only to certain acoustic cues in the input like fundamental frequency and vowel lengthening rather than to other cues like pausing (Jusczyk, Hirsh-Pasek, Kemler Nelson, Woodward & Piwoz, 1992). Not only do children attend to certain cues over others within a particular input, but they also differentially attend to different inputs over others across developmental time. Thus, prosodic cues are more heavily weighted within the first year of life while semantic and social cues become more prominent during the second year and grammatical cues more weighted during the third year. Language comprehension is affected by the change in the weightings of the input cues. Figure 1 depicts these changes over time.

---Insert Figure 1 about here---

Fourth, changes in the weighting of cues from the input create phase shifts in the development of comprehension. These re-weightings of the input occur either when children require more elaborate language structures to achieve their communicative goals (Bloom, 1993) or when they fail in their communicative attempts -- thus misinterpreting passive sentences, 'The man was bitten by the dog' as active sentences, 'The man bit the dog' because they attend to the order of the content words in the sentence.

Fifth and finally, one key assumption of the model is that the development of language comprehension through the phase shifts is empirically testable. Indeed, there is already a good deal of evidence to support the conceptualization of the phases suggested in the model. Current research is underway to assess the re-weighting hypotheses in both the comprehension of grammar and of words.

In what follows, we very briefly give the flavor of the model with some of the evidence that tends to be consistent with it. We then examine how such a model might explain the logical problems of language acquisition, finding the units and relations of language, and how it compares metatheoretically with the other models representing the new wave of research.

3.5 Three phases and some supporting evidence

3.5.1 Phase I.

In this model, infants are said to already have some language comprehension from the second half of the first year of life as they attempt to make sense of the flux of acoustic and visual information surrounding them. Their job is seen as twofold: first to segment the fluid speech into some acoustically relevant chunks that will become language relevant units, and second, to use some of these acoustic units to assist them in discovering the objects, actions and events that surround them. Both of these initial processes are rather shallow and require only that the child attend to certain cues in the acoustic and visual environment and that they perform distributional and correlational analysis that will enable them to internalize frequently encountered units and events. Hirsh-Pasek and Golinkoff liken the first steps of the internalization process to "cinema verite" in film. No interpretation occurs here. Indeed, in this first segmentation phase the child literally stores a number of meaningless but regular acoustic forms that can later become language relevant.

There is considerable support for the notion that speech is first segmented and extracted in language-relevant ways (see also Peters, 1983), and that these segments are further broken down and analyzed into their component parts. Hirsh-Pasek, Kemler-Nelson, Jusczyk, Wright, Druss, and Kennedy (1987, see also Jusczyk et al, 1992; among others) note that infants of just 4 and a half months of age are sensitive to the acoustic markings that correlate with clauses and that 9 month olds are sensitive to markings correlated with phrases like nouns and verbs.

There is also evidence that infants can do distributional analysis across phonological and rhythmic properties of the speech input even though they do not technically comprehend the meaning of these inputs. By way of example, Jusczyk and his colleagues (see Jusczyk, 1997) and Saffran, Aslin and Newport (1996) have demonstrated that very young infants of 6 to 8 months of age are sensitive to and perform distributional analysis across phonological patterns. Thus, infants appear to rely quite heavily on the acoustic system to get a leg up on early language units. This same literature suggests that these infants create a storehouse of acoustic information that can later be used for more sophisticated processing (see also Gerken, 1996 for a review).

While this segmentation and categorization is going on, Hirsh-Pasek and Golinkoff also speculate that children can use this 'acoustic packaging' to supplement their information about the linkage between sounds and events. They hypothesize that children make unbiased observations of the events that occur in the world, noting, perhaps, the temporal contiguities of sound, movement, cause and effect, as they take place in the environmental tableau. At this phase of input segregation, a young infant may observe, for example, that certain objects in the world (say, the family cat) tend to co-occur with certain sounds (say, the word "CAT" and other references to cat attributes) more than other sounds. Further, the infant may notice that activity on the cat's part may be highly correlated with verbal comment about that activity and that these event segments may be similarly bracketed, such that the sound streams begin and end in concert with events that are observed in the world. It is important to note that while this phase is catalogued as the beginning of language comprehension, there is really nothing particularly linguistic about this phase. We do not place unusual constraints on

the child's attention, save that they notice these things, and their likelihood of occurring together.

At the preliminary phase of perceptual segmentation and extraction phase, the child begins to construct what Mandler (1988, 1992) calls "image schemas". These contain perceptual primitives such as AGENCY, CAUSALITY, PATH and CONTAINMENT. Further, this initial acoustic packaging may help the child to carve up events in the world, by providing a template or overlay onto ongoing scenes the child observes or the repeated and standard routines in which the child participates (Nelson, 1985). Although we don't expect that the child is making linguistic judgments about these packages, we argue that the structure of heard language may constrain possible event units in the perceptual arena. Evidence already exists showing that infants are more likely to attend to a visual event when it is highlighted by speech (Horowitz, 1974), and it seems reasonable that a first step towards building representations that may have linguistic correlates is to attend to those events that are being described or otherwise referred to linguistically. Further, it seems reasonable to assume that children will also use social cues, especially those present in discourse, to help tie the ribbon on their perceptual packages, further assisting their segmentation and storage of "macroevents" and routines for later internal analysis. Much of this is formulation is speculative but testable, and Hirsh-Pasek and Golinkoff offer some novel verification approaches for these predictions, some of which are currently being investigated in their laboratories. Indeed, it is difficult, to imagine a situation wherein something very much like this acoustic packaging did not occur as the first step in constructing linguistic representations in the first months of life as children try to integrate the multiple sources of the coalition in an attempt to make meaning in their world.

3.5.2 Phase II.

Hirsh-Pasek and Golinkoff go on to describe the next step, a process of interpreting these perceptually stored acoustic packages. Beginning in the later months of the first year, infants are presumed to possess a small collection of these highly salient event packages that can be further analyzed into components that

may have direct linguistic correlates like subject, verb and object. During this phase, infants move beyond prosodic mapping to what they call semantic mapping; in the coalition government, the voting power of the sound system gives way as the semantic system begins to assert itself. Children begin to use the correlates of prosody, semantics, and even syntactic cues (e.g., articles signifying nouns) to map individual words to their referents and thus to 'buy' a much more elaborate and rich system of communication and representation (Bloom, 1993).

One remarkable hallmark of Phase II interpretation is the growth of the lexicon. This remarkable feat, sometimes referred to as the vocabulary spurt, occurs after the child has already acquired roughly 50 words in production. The spurt seems to be a qualitative jump in learning - estimates are that between 7 and 9 new words are learned, albeit incompletely, daily (Carey 1982). To explain this rapid lexical growth, some researchers have suggested that the child must possess a set of constraints or principles to enable so-called "fast-mapping" between the phonological and semantic representations of words (Slobin, 1982, 1985; Golinkoff, Mervis & Hirsh-Pasek, 1994).

Indeed, Golinkoff, Mervis & Hirsh-Pasek (1994) offer a two-tiered model of linguistic principles, developmentally realized, that may aid in such fast mapping of words with their referents: word-learning principles that are also considered to be developmentally emergent, in a coalition government fashion, out of the dynamic interrelation of multiple cues (Hollich, Hirsh-Pasek, & Golinkoff, in press). For example, initial word mapping may be governed by simple associative learning effects: words and objects are associated temporally and spatially (temporal contiguity). Later, children abandon this simple associative strategy and realize that words *refer* or somehow "stand-for" objects, rather than simply being associated with them. This realization frees the child from the environmental requirement that all of the coalescing cues are there to support the word-referent connection.

The notion that word learning principles might themselves be developmental is consistent with work by Bloom (1993) and Jones and Smith (1993) and colleagues who have extended these findings to pre-vocabulary-spurt infants. Preliminary results suggest that these infants do, as predicted, use simple associative cues, like temporal contiguity and saliency to determine

reference, while ignoring other cues like eye-gaze (Hollich, Hirsh-Pasek & Golinkoff, 1996).

Word learning is one of the defining characteristics of this period as are the rudiments of a grammatical system that is defined through the semantic functions and pragmatics. (e.g. Concepts like agents, actions and objects define grammatical categories, see for example, Bowerman, 1973; MacNamara, 1982; among others). What is striking at this age is the reliance on semantics or pragmatics as governing language comprehension. Semantically implausible sentences, for example, are simply misunderstood such that sentences like, 'Baby feeds mommy' will be understood as, 'Mommy feeds baby.' It is interesting that children at this age can attend to some grammatical cues like constituent structure and word order (see for example, Hirsh-Pasek & Golinkoff, 1996; Naigles, 1990; P. Bloom, 1990; among others), but that grammatical reliance gives way to semantic probability when the two systems are put into direct conflict. Note again that the child has many inputs at his disposal and differentially weights these inputs for the purpose of comprehension.

3.5.3 Phase III.

By the time children are well into the vocabulary spurt, they are also recognizing certain regularities in the words they have learned, and the ways in which these words are arranged sententially to convey meanings. Words are categorized into form classes (open and closed class) as well as grammatical classes (noun and verb). Often these category assignments can be bolstered by prosodic variables; for example, in English, grammatical class can often be predicted by number of syllables and stress patterns. Nouns tend to have more syllables than verbs, and bisyllabic words with syllable-initial stress tend to be nouns more often than verbs (cf. RECord vs. recORD) (Kelly, 1992). Also during this second phase, children are beginning to comprehend multi-word sentences and the complex grammatical relations indicated by word order. This ability is only readily apparent, however, when the complex social, semantic and syntactic

cues are all "in alignment." This redundancy of cues is necessary here to bolster what Hirsh-Pasek and Golinkoff term the child's "fragile comprehension."

Beginning by about 24 months, however, this heavy reliance on a coalition of cues wanes as the child's syntactic system becomes more robust. It is one of the fundamental features of a linguistic system that the meanings conveyed by sentences are often (perhaps mostly) abstract and describe past or future events, feelings, and the like. So a child who expects language to only describe those events or objects immediately present would not get very far. Instead, as children grow more aware of the complex relationships among people and objects and events in the world, and as their representations about these relations become more sophisticated, children will need to formulate (or discover) ways of communicating these ideas (Phase III). This is essentially a paraphrase of L. Bloom's (1993) Principle of Elaboration, but notice here how this idea is also fundamentally consistent with representational redescription as Karmiloff-Smith conceived the term. Notice also that this is not, strictly speaking, a failure-driven model, although we expect that the child is highly motivated by certain inadequacies in their current repertoire of linguistic forms. One strong impetus for further representational refinement is the pressure to communicate abstract propositional ideas about feelings, past events, and the like.

How can researchers distinguish between a Phase II and a Phase III child, a child who is using syntactic cues and not simply semantic cues to meaning? Many argue that early semantic understanding is facilitated by what MacNamara (1982) called basic sentences, characterized by a simple agent-action-patient format (subject-verb-object). If children understand the individual meanings of the words involved, and further, expect these sentences will have the semantic meaning of "who did what to whom" they will be accurate a good deal of the time. Studies using the intermodal preferential looking paradigm demonstrate that one-word speakers can comprehend word-order in sentences like "She is kissing the keys" or "Big Bird tickled Cookie Monster," but the most conservative assumption is that the child is engaging in a semantic, rather than syntactic interpretation (see Pinker, 1984; Bowerman, 1973). One way of showing movement to syntactic understanding would be to demonstrate comprehension of sentences that could only be understood by using syntactic interpretations.

One such type of sentence is the English passive, a construction that occurs rather later in children's productions, and which violates word-order assumptions of basic sentences. (Other, more complex syntactic analyses are provided in Hirsh-Pasek & Golinkoff, 1996, and we refer the interested reader to this source for discussion).

The English passive violates standard subject-verb-object form by introducing the closed-class word 'by' and the closed- class morphology -ed on the verb: "Big Bird is tickling Cookie Monster" becomes "Cookie Monster is tickled by Big Bird." In order for a child to correctly identify the actor and patient in this sentence, the child must essentially ignore word-order and focus on closed-class morphology as a cue to meaning. This is especially interesting in that closed-class items are routinely dropped from young children's productions, presumably because they tend to be unstressed in speech to children (Pinker, 1984). Recent evidence suggests however that even though children omit these items from their speech, they are nonetheless sensitive to this higher level grammatical information in comprehension (Golinkoff, Hirsh-Pasek & Swiesguth, in press; Shipley, Smith & Gleitman, 1969; Taylor & Gelman, 1989; see also Gerken 1996 for a review). These data along with others help to explain why children in Phase III are able to correctly interpret passive sentences, whereas children in Phase II misinterpret them in a prototypical (albeit incorrect) agent-action-patient format.

3.6 The Coalition Model: Similarities and differences with other models in the emergentist perspective

In this model language comprehension is described as a move from a non-linguistic, perceptual-acoustic system to one that is semantically-driven, to one that is finally rich with syntactic understanding (see Figure 1). This model provides a clear and rigorous application of the emergentist program, in that development truly rules the day. The model is also consistent with those theories that stress boundary conditions in that children begin the process of language comprehension constrained to notice certain cues over others; cues that will lead

them towards the discovery of grammatical units and relations. Indeed, the discovery of language units is nicely accounted for in this model as progressing from attention to acoustic cues (nouns are marked by high stress at the ends of sentences), to semantic cues (these acoustic units generally correspond to persons, places and things -- see also the semantic bootstrapping theories of Grimshaw, 1981, Pinker, 1984), to syntactic cues for form class assignment (nouns are followed by 'the' and 'a').

As is evident above, the coalition model borrows the emergentist approach to solve the unit extraction and identification problem. Yet, this model also differs from prior emergentist models by suggesting that a coalition of information is available to the child at all times and that children mine the correlations between these systems to solve the language learning problem. That is, in the other models reviewed, an input domain like syntax would itself be an emergent property of the theory rather than an available but less heavily relied upon system of information. Evidence from our laboratory, however suggests that children are sensitive to grammatical cues in the input at a very early age and that they can use these cues even though they do not often use these cues (see Hirsh-Pasek & Golinkoff, 1996, for a review). By way of example, children who have yet to combine their first words are nonetheless sensitive to constituent structure and to word order cues in the input. It is hard at this point in the development of the emergentist program to imagine how a theory that does not provide some a priori syntactic cues to the child could ever derive them. Thus, Hirsh-Pasek & Golinkoff suggest that some rudimentary cues to grammar must be available to children at the time when they learn language so that they can use them to bootstrap their way in to more sophisticated systems. The jury is out as to whether a truly emergentist theory will someday supplant the need for this jump start: as to whether we will eventually be able to explain both how children identify the units of grammar and learn the relationships between these units that signify mastery of the human language.

In sum then, Hirsh-Pasek and Golinkoff's coalition model provides one example, indeed one of the first examples, of how the principles of the new metatheory can be applied in explaining early language development. Using this model, they provide an empirically testable theory of how innate beginnings

(boundary conditions) and emergent development (upward causation) can work in tandem to account for one significant aspect of human development.

4 THE FUTURE OF EMERGENTISM

In the foregoing sections, we offered the likely proposition that something of a quiet mini-revolution has taken place in the world of cognition and in particular, in the area of language development. This revolution of thought has largely abandoned old issues of nature-nurture and initial modularity. Instead, the change afoot in the language acquisition arena seems to be the enthusiastic rendering of these old ideas in a new emergentist uniform, complete with a qualitatively different role for the social environment, the sounds of language, and perceptual biases or constraints that even neonates may possess. This mini revolution is in its inception within the field of cognitive development and it is yet to be seen how the theory will stand the test of time.

Like any new theory, emergentism will have to prove that it is not just a redescription of old ideas. It must prove itself specific enough to accommodate the old facts, and powerful enough to predict new ones. To be truly useful, the theory will also have to answer some of the stubborn and persistent properties of language acquisition; properties which have plagued so many others (like an adequate explanation of how children acquire the hierarchical units and structurally dependent relations of grammar). It will also have to be the guiding light for newer methodologies that examine variability and the weighting of cues over time. Like any new theory, emergentism -- though still in its infancy -- does have its critics. In this final section, we briefly raise some of the critical rumblings that can be heard throughout the field, we offer some speculations about the types of methodologies that will be required in the new perspective and close by suggesting that emergentist thinking might provide just the right sort of theoretical medicine to allow psychologists to move beyond he feudal wars and into an exciting new era of research.

4.1 Evaluating the "New View."

Two questions dominate the criticisms that can be heard throughout the land. The first questions whether there is anything new here. The second asks whether such complex, non-linear and interactive systems can ever be falsifiable. Let's address each in turn.

4.1.1 Is there anything new here ?

Some critics of the new approach have posed the question of whether there is anything new here or whether the emergentist theory is simply old wine in new bottles? Are we substituting redescription for explanation? (Bloom, 1992). There are two forms that this argument has taken. In the first form of this argument, theorists ask whether the new innatism merely displaces structural innateness with process innateness. That is, for the earlier theories in language development, language structure was thought to be inborn and the job of the child was to discover these internal rules by attending to computing the relations in the input. Today's brand of nativism puts the innate material in the boundary conditions or constraints that guide learners toward relevant information in the input -- processes that ultimately serve to constrain structure through the back door. Perhaps emergentism, then has simply displaced the problem of the homunculus without solving it!

While this challenge is a serious one, the emergentist position has taken great pains to suggest that the boundary conditions being proposed are really quite different than those endorsed earlier. First, in many theories the innate processes are thought to be the product of evolution and of biological predisposition. Second, the burden of the new theories is not to ask how input triggers a pre-formed choice of internal structures, but how these predispositions work in concert with the input and task demands to allow for the development of sophisticated and tightly organized structures like language.   Thus, at minimum,

the emergentist theory with its connectionist proofs that complex behaviors arise jointly from a set of predispositions and simple behaviors forces us to truly 'rethink innateness.' We cannot make hand-wringing appeals to pre-existing knowledge to explain the occurrence of complex behavior in the growing individual.

A second way in which the 'is there anything new' criticism manifests itself is in the direct attack on computer modeling as an implementation of human behavior. This echoes prior debates within psychology (see for example, Rumelhart & McClelland, 1986; Fodor & Pylyshyn, 1988; Pinker & Prince, 1988; Clark & Karmiloff-Smith, in press). While we applaud the attention to architectural and timing constraints implicit in this modeling endeavor, are we just making implementable machines? Are we saying anything meaningful about human cognition? Is it possible to move in the direction of a machine-implemented connectionist model and still remain true to the original goal of explaining human cognition? And even if we construct machinery which behaves in every reasonable way the way humans do, if it passes a Turing test of the highest magnitude, have we come any closer to understanding human behavior? Or have we simply sidestepped the issue, fortifying ourselves with a complex and elegant system that only seems to provide some insights?

Obviously, we believe this approach has merit. Ignoring for the moment the enormous practical benefits of having a thinking computer which could respond as a human, there are at least four other reasons to be encouraged by connectionist modeling: 1) Simply thinking about building such machines focuses on the right questions: how do we think; what functionally do we really do when we think; what is input is needed to the thinking process; what constraints need to be built in; how specifically can this be implemented? etc.; 2) Any detailed study of complex interacting networks is bound to help us when it comes to making sense of the neurophysiological data; 3) We can test, lesion and experiment with models in ways that would be completely unethical with humans or animals. Thus even if the network is completely wrong, such studies could still suggest relevant variables; 4) It gives us a sense of starting points. If a completely unbiased network could learn grammar from scratch, then constraints theories have some problems. If it can't, then we can explore what specifically

needs to be built in before the network can learn a grammar. The networks themselves, could thus be used to constrain subsequent theorizing.

4.1.2 The Falsifiable Question.

One further criticism of the emergentist approach is that it is hard to build an *a priori* theory about development. Because so much of development now is seen as flux and variability, the proximal causes for change are often difficult to detect and empirically verify. If observation always changes the thing observed, if all data are theory laden, then we may have compounded an already difficult problem by piling up data points.

The response to this is yes, this does indeed make things much more difficult. On the other hand, no one ever said finding the truth was easy. We argue that single cause explanations, while certainly simple, are by their nature deceiving. Moreover, even if observation affects the thing observed, it is still possible to infer the processes and forces involved: even if one of them happens to be the observer. Rather than simply to give up, the field will have to adopt new methodologies and techniques that either model the ways in which multiple inputs interact or can assess the ways in which children calibrate their learning to these inputs over time.

4.2   Methodological Implications.

As noted above, if the new emergentism is to be taken seriously, we will need to refine our looking glass (see also Tucker & Hirsh-Pasek, 1993; Hirsh-Pasek, Tucker & Golinkoff, 1996, for additional methodological discussion). If we are mapping domain-specific (microdomain) changes in linguistic comprehension, syntactic understanding, prosodic intuitions, and the like over time, then we must

of necessity adopt a long view of the problem. This requires longitudinal research, multiple measures of behavior, and time-slices of behavior more time-constrained and context-sensitive than those most developmentalists have yet attempted.

Likewise, variability among individuals must be taken seriously. We must stop squinting our eyes when we look at on-line behavior and developmental milestones. We must no longer obscure differences by averaging our observations together. Thus, the mean behavior is no longer appropriate, because such an averaging process, while perhaps methodologically and theoretically expedient, has left us with too many holes to fill: too many 'statistical outliers' whose behavior is interesting but doesn't fit in with our established theories of language development.

Moreover, (Thelen & Smith, 1994) patterns of variability could provide critical information regarding the underlying processes and constraints. Mathematically speaking, any pattern can be seen as the result of a limited number of underlying functions. Thus, accurate specification of the types and kinds of variability, helps one know better what kinds of causes to seek. Of course, pragmatic time and cost demands prohibit this kind of research to some degree, but the tendency of cross-sectional data to exaggerate the stage-like quality of development and obscure individual variation must be acknowledged as a real problem in the interpretation of traditional developmental data.

4.3 Conclusions.

In sum, we have argued that there is a much needed change afoot in cognitive psychology that is being played out in the area of cognitive development that has enormous consequences for the theory of language development. It is a change that is being seen widely in other academic disciplines from physics to biology; from economics to political science. In part, this change is the focus on change itself and the dynamics of any highly complex system. This focus manifests itself as an increasing awareness of the ways in

which higher order structures can emerge from lower order interactions (upward causation), the ways higher order interactions can affect lower levels (downward causation), and a renewed focus on the kinds of boundary conditions and phase shifts that characterize any dynamic system.

As we attempted to show in this paper, the area of language development will prove a major testing ground for this new theory. Like so many areas, the field has been plagued by a series of feudal wars in which the participants tended to endorse one extreme explanation to the exclusion of others. However, as three recent theories illustrate, the newer emergentist view provides an escape from this quandary, and re-maps the path for future experimentation in such a way as to combine the best of previous theories and move beyond them. Indeed, in our own work, the coalition model allows us to adopt some of the emergentist assumptions and to test them in the highly debated arena of language development.

We are just beginning to apply these new lessons and to find out whether this hybrid approach represents more than lipservice to old theoretical persuasions, or whether this may indeed signify the start of something akin to a scientific revolution. As these ideas are applied to language development, we are cautiously hopeful. Any perspective that advocates a more rigorous empirical proving ground for complex multivariate interactions among causal components is worth exhausting. Any theory or class of theories that attempts a dialogue among polar extremists is sorely needed. And any explanation that places fundamental power on the backs of formal and final Aristotelian causality, toting complex interactions in lieu of more facile efficient narratives, is ultimately a more fruitful way to think about the problem. What remains, of course, is the messy empirical work.

Endnotes

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Figure Captions:

Figure 1: A coalition model of language comprehension. Different cues are differentially weighted (as indicated by shading) during the course of development.

Phase I	☐
Phase II	▨
Phase III	▨

prosody

lexical
information
morphology

semantics

Language
comprehension
in the child

social
contex

syntax

environmental
context: action
objects