ON THE EMERGENCE OF GRAMMAR FROM THE LEXICON

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Where does grammar come from? How does it develop in children? Developmental psycholinguists who set out to answer these questions quickly find themselves impaled upon the horns of a dilemma, caught up in a modern variant of the ancient war between empiricists and nativists. Indeed, some of the fiercest battles in this war have been waged in the field of child language. Many reasonable individuals in this field have argued for a middle ground, but such a compromise has proven elusive thus far, in part because the middle ground is difficult to define.

So let us begin with some definitions. The core of this debate is about epistemology, a branch of philosophy that we can define as "The study of knowledge, its form and source, and the process by which it comes to be." Within this framework, empiricism can be defined as "The belief that knowledge originates in the environment and comes into the mind/brain through the senses," an epistemology that can be traced back to Aristotle, with variations over the centuries by Hume, Locke and the American Behaviorist School. Nativism can be defined as "The belief that fundamental aspects of knowledge are inborn, and that experience operates by filling in preformed categories, selecting, activating or "triggering" these latent mental states." This epistemology can be traced back to Plato, with historical variations that have included Kant and Descartes.

Many researchers follow the lead of Noam Chomsky, subscribing explicitly to the nativist doctrine as we have just defined it. Chomsky himself has consistently and clearly articulated a nativist approach to the nature and origins of grammar, treating grammar as an organ of the brain not unlike an organ of the body, unfolding on a strict maturational schedule, governed by a specific genetic program. Some sample quotes from Chomsky (1988) illustrate these claims, including an unambiguous endorsement of Plato:

> "The evidence seems compelling, indeed overwhelming, that fundamental aspects of our mental and social life, including language, are determined as part of our biological endowment, not acquired by learning, still less by training, in the course of our experience. Many find this conclusion offensive. They would prefer to believe that humans are shaped by the environment, not that they develop in a manner that is predetermined in essential respects." (p. 161).

> "Now this illustrates a very general fact about biology of organs. There has to be sufficiently rich environmental stimulation for the genetically determined process to develop in the manner in which it is programmed to develop. The term for this is "triggering"; that is, the experience does not determine how the mind will work but it triggers it, it makes it work in its own largely predetermined way." (p. 172)

> "How can we interpret [Plato's] proposal in modern terms? A modern variant would be that certain aspects of our knowledge and understanding are innate, part of our biological endowment, genetically determined, on a par with the elements of our common nature that cause us to grow arms and legs rather than wings. This version of the classical doctrine is, I think, essentially correct." (p. 4)

Of course Chomsky acknowledges that French children learn French words, Chinese children learn Chinese words, and so on. But he believes that the abstract underlying principles that govern language in general and grammar in particular are not learned at all, arguing elsewhere that "A general learning theory … seems to me dubious, unargued, and without any empirical support" (Chomsky, 1980).

Because this theory has been so influential in modern linguistics and child language, it is important to understand exactly what Chomsky means by "innate." Everyone would agree that there is something unique about the human brain that makes language possible. But in the absence of evidence to the contrary, that "something" could be nothing other than the fact that our brains are very large, a giant all-purpose computer with trillions of processing elements. Chomsky's version of the theory of innateness is much stronger than the "big brain" view, and involves two logically and empirically separate claims: that our capacity for grammar is innate, and that this capacity comprises a dedicated, special-purpose learning device that has evolved for grammar alone. The latter claim is the one that is really controversial, a doctrine that goes under various names including "domain specificity", "autonomy" and "modularity." Putting the separable but correlated claims of innateness and domain specificity together, Kandel, Schwartz and Jessell (1995) provide a concise textbook summary of Chomsky's theory that provides a fair representation of this view as it has been received and interpreted outside of linguistics, in the outer reaches of cognitive science and neuroscience:

> "Chomsky postulated that the brain must have an organ of language, unique to humans, that can combine a finite set of words into an infinite number of sentences. This capability, he argued, must be innate and not learned, since children speak and understand novel combinations of words they have not previously heard. *Children must therefore have built into their brain a universal grammar, a plan shared by the grammars of all natural languages" (p. 639, italics ours)*

Strong and explicit illustrations of this view can also be found within child language as well, with emphasis on the genetic and the neural bases of a mental organ for grammar:

> "A distinguishing feature of recent linguistic theory, at least in the tradition of generative/transformational grammar, is that it postulates universal (hence, putatively innate) principles of grammar formation, rather than characterizing the acquisition of language as the product of general cognitive growth...This theoretical framework is often referred to as the theory of Universal Grammar, a theory of the internal organiza-

tion of the mind/brain of the language learner" (Crain, 1991).

"It is a certain wiring of the microcircuitry that is essential....if language, the quintessential higher cognitive process, is an instinct, maybe the rest of cognition is a bunch of instincts too—complex circuits, each dedicated to solving a particular family of computational problems posed by the ways of life we adopted millions of years ago." (Pinker, 1994, pp. 93, 97)

"It is not unreasonable to entertain an interim hypothesis that a single dominant gene controls for those mechanisms that result in a child's ability to construct the paradigms that constitute [grammatical] morphology." (Gopnik & Crago, 1991, p. 47)

In contrast with the relatively large group of linguists and psycholinguists who are willing to embrace a nativist view, few modern investigators proclaim themselves to be empiricists as we have defined it here. Instead, those who disagree with Chomsky tend to argue in favor of an interactionist account, where learning plays a central role but does so within biological constraints. In its weaker form, interactionism constitutes little more than an eclectic mix of nativist and empiricist claims. A stronger form of interactionism, alternatively called "constructivism" or "emergentism," constitutes a genuine third alternative. However, emergentism is also a much more difficult idea than either nativism or empiricism, and its historical roots are less clear. In the 20th century, the constructivist approach has been most closely associated with the Swiss psychologist Jean Piaget (e.g., Piaget, 1970). More recently, it has appeared in a new approach to learning and development in brains and brain-like computers alternatively called "connectionism," "parallel distributed processing" and "neural networks" (Elman et al., 1996; Rumelhart & McClelland, 1986), and in a related theory of development inspired by the nonlinear dynamical systems of modern physics (Thelen & Smith, 1994). To understand this difficult but important idea, we need to distinguish between simple interactions (black and white make gray) and real cases of emergence (black and white get together and something altogether new and different happens).

In an emergentist theory, outcomes can arise for reasons that are not obvious or predictable from any of the individual inputs to the problem. One might expect, for example, that the spherical shape of soap bubbles derives from some specific property of soap; instead, it turns out that soap bubbles are round because a sphere is the only possible solution to achieving maximum volume with minimum surface (i.e., their spherical form is not explained by the soap, the water, or the little boy who blows the bubble). The honeycomb in a beehive takes an hexagonal form because that is the stable solution to the problem of packing circles together (i.e., the hexagon is not predictable from the wax, the honey it contains, nor from the packing behavior of an individual bee—see Figure 1). Jean Piaget argued that logic and knowledge emerge in just such a fashion, from successive interactions between sensorimotor activity and a structured world. A similar argument has been made to explain the emergence of grammars, which represent the class of possible solutions to the problem of mapping a rich set of meanings onto a limited speech channel, heavily constrained by the limits of memory, perception and motor planning (MacWhinney & Bates, 1989). Logic and grammar are not given in the world, but neither are they given in the genes. Human beings discovered the principles that comprise logic and grammar, because these principles are the best possible solution to specific problems that other species just simply do not care about, and could not solve even if they did. Proponents of the emergentist view acknowledge that something is innate in the human brain that makes language possible, but that "something" may not be a special-purpose, domain-specific device of the sort proposed by Chomsky and his followers, i.e. an autonomous device that evolved for language and language alone. Instead, language may be something that we do with a large and complex brain that evolved to serve the many complex goals of human society and culture (Tomasello & Call, 1997).

So the debate today in the field of language development is not about Nature vs. Nurture, but about the "nature of Nature," that is, whether language is something that we do with an inborn language device, or whether it is the product of (innate) abilities that are not specific to language. The horned beast in Figure 2 (below) provides another metaphor of the process by which Nature finds idiosyncratic outcomes through simple quantitative change in a much more general structure. The elegant headgear displayed in Figure 2 is striking; confronted with such an odd display, we are tempted to speculate about its specific purpose for that species (e.g., to appeal to females, to frighten competing males). However, D'Arcy Thompson (1917/1968) pointed out long ago that the curvature of a more general "standard horn" will twist into just such a shape if the animal continues to grow past the age at which horn growth normally comes to an end. Hence a relatively simple quantitative change in patterns of growth can yield an exotic and (apparently) peculiar outcome (of course, the female sheep may have grown quite fond of the resulting display in the intervening years, but that is another story).

Yet another metaphor for the evolution of grammar comes from the giraffe (Figure 3). Consider in particular the giraffe's neck, a striking adaptation if ever there was one. Because of this adaptation, giraffes can feast on leaves high up in the trees, with no competition from birds, monkeys and other creatures that reach the same heights by other means. Should we conclude that the giraffe's neck is a "high-leaf-eating organ"? Not necessarily. First of all, the giraffe's neck is still a neck, i.e., it still does all the jobs that necks perform in less specialized species. Second, the giraffe's neck built out of a basic blueprint that is used in all vertebrates, e.g., it has the same number of bones that necks contain up and down the mammalian line, elongated to provide extra potential for reaching up high in the trees. As a result of this particular adaptation (resulting from quantitative changes in the Basic Neck Plan), other adaptations have been necessary as well, including cardiovascular changes (to pump blood all the way up to the giraffe's brain), shortening of the hindlegs relative to the forelegs (to ensure that the giraffe does not topple over), and so on. If we insist that the neck is a leaf-reaching organ, then we have to include the rest of the giraffe in that category too, including cardiovascular changes and adjustments in leg length.

We suggest that the human "grammar organ" has evolved in a similar fashion: Because of quantitative adjustments in neural mechanisms that exist in other mammals, human beings have walked into a problem space that other animals cannot perceive, much less solve. However, once it finally appeared on the planet, it is quite likely that language itself began to apply adaptive pressure to the organization of the human brain, just as the leaf-reaching adaptation of the giraffe's neck applied adaptive pressure to other parts of the giraffe. All of the neural mechanisms that participate in grammar still do other kinds of work (i.e. they have kept their "day jobs"), but they have also grown to meet the language task. Candidates for this category of "language-facilitating mechanisms" might include our social organization, our extraordinary ability to imitate the things that other people do, our excellence in the segmentation of rapid auditory stimuli, our fascination with joint attention (looking at the same events together, sharing new objects just for the fun of it), and perhaps above all our ability to create and manipulate symbols, letting one object, sound or action stand for an object, event or idea that is not currently present or perceivable in the immediate environment (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979; Bates, Thal, & Marchman, 1991). These abilities are present in human infants within the first or second year, and they are clearly involved in the process by which language is acquired. Thus, even though none of these basic cognitive and communicative abilities are specific to language, they permit the emergence of language in general, and grammar in particular.

In this chapter, we will explore a particular variant of the emergentist approach to grammar, emphasizing the union between grammar and the lexicon. ***We will define grammar as the class of possible solutions to the problem of mapping back and forth between a high-dimensional meaning space with universal properties, and a low-dimensional channel that unfolds in time, heavily constrained by limits on information processing*** (see also MacWhinney & Bates, 1989). This is a constraint satisfaction problem, and it is also a dimension reduction problem. In problems of this kind, complex solutions are likely to emerge that are not directly predictable from any individual component (Elman et al., 1996; Rumelhart & McClelland, 1986). Grammars do not "look like" anything else that we do—not even the quintessentially linguistic act of naming. However, such idiosyncratic products can be explained without postulating a grammar-specific learning device or a grammar-specific neural mechanism in the brain. Two related lines of evidence will be marshaled in favor of this approach. First, we will provide evidence for a strong form of lexicalism, showing that grammar and the lexicon are acquired and mediated by the same mental/neural mechanisms. Evidence for this claim will include the strong relationship between grammar and lexical development during the early stages of language learning, the striking overlap between lexical and grammatical symptoms observed in neurological patients, and the absence of evidence for a systematic difference in the cortical areas that mediate grammatical and lexical information. Second, we will include evidence suggesting that the mental/neural mechanisms responsible for both lexical and grammatical processing are not unique to language. Like the giraffe's neck (which is highly specialized but also handles many tasks), the neural mechanisms that "do" language also "do" a lot of other things.

The link between emergentism and the lexicalist approach to grammar is also discussed by Goldberg (this volume), but is important enough for our arguments here that it merits some attention before we proceed. The autonomy of grammar from other aspects of language has been a key element in Chomsky's arguments for innateness. A critical aspect of this argument revolves around the Poverty of the Stimulus: Grammars (as Chomsky defines them) are not learnable in finite time in the absence of negative evidence (i.e., in the absence of clear feedback concerning forms that are <u>not</u> possible within the language—see especially Gold, 1967); because children do not receive systematic negative evidence, they must possess enough innate knowledge about their grammar to permit learning to go through. In other words, grammar cannot be learned "bottom up," through the application of inductive learning procedures, because such learning requires exploration of an infinite search space. Even if this were true, one still might argue that grammar could be learned "top down," through the application of deductive procedures that map linguistic forms onto a finite set of meanings, including meanings that are not specific to language (e.g., negation, agency, causality, location and change of location). This meaning-driven approach to the acquisition of grammar might narrow the search space enough to permit successful learning in finite time. It also requires no assumptions about the modularity/autonomy of grammar, because the same "top down" mechanisms that are used to acquire words (e.g., mapping the sounds CAT and DOG onto their respective categories) can be used to acquire grammatical structures (e.g., mapping nominative case and preverbal position onto an emerging category of agency). To counter such claims, Chomsky and his colleagues have underscored the peculiarity and functional opacity of grammar, emphasizing the difference between grammatical development and word learning. Although word learning may involve innate constraints of some kind (for a discussion and rebuttal, see Smith, this volume), most nativists concede that the lexicon is finite, varies markedly over languages, and must be learned (at least in part) through brute-force inductive procedures that are also used for other forms of learning, linguistic and nonlinguistic (Bates & Elman, 1996; Saffran, Aslin & Newport, 1996). Because core grammar is universal, functionally opaque and infinitely generative, the domain-general procedures that are used to acquire words cannot (it is argued) work for the acquisition and processing of grammar (cf. letters in *Science*, 1997, by Pesetsky, Wexler, & Fromkin; Pinker; Jenkins, & Maxam; Clark, Gleitman, & Kroch; Newport, Aslin, & Saffran). Additional arguments in favor of this dual-mechanism approach include (a) differences in the onset and pattern of development observed for words vs. grammar in normal children, (b) patterns of dissociation between grammar and the lexicon in children and adults with language disorders, and (c) different patterns of brain localization for lexical vs. grammatical processing in lesion studies and in studies of normal adults using neural imaging techniques (e.g., Jaeger et al., 1996; Pinker, 1991, 1994; Ullman et al., 1997).

In this chapter, we will argue against the autonomy of grammar, in favor of a unified lexicalist approach to the processes by which grammar is acquired, used and represented in the brain. This is only one part of a more general emergentist theory of grammar, but it counters many of the arguments that have been used to date against the emergentist account. Although we are building a theory of linguistic performance, our lexicalist account is compatible with a number of independently motivated proposals within modern linguistics. A general trend has characterized recent proposals in otherwise very diverse theoretical frameworks within linguistics: more and more of the explanatory work that was previously handled by the grammar has been moved into the lexicon. In some frameworks (e.g., recent versions of Chomsky's generative grammar—Chomsky, 1981, 1995), the grammatical component that remains is an austere, "stripped down" system characterized by a single rule for movement and a set of constraints on the application of that rule. In this theory, the richness and diversity of linguistic forms within any particular language are now captured almost entirely by the lexicon, which includes complex propositional structures and productive rules that govern the way those elements are combined. The trend toward lexicalism is even more apparent in alternative frameworks like Lexical Functional Grammar (Bresnan, 1982, 1996) and Head-Driven Phrase Structure Grammar (Pollard & Sag, 1994). It reaches its logical conclusion in a framework called Construction Grammar (Fillmore, Kay, & O'Connor, 1988; Goldberg, 1995 and this volume), in which the distinction between grammar and the lexicon has disappeared altogether (see also Langacker, 1987). In Goldberg's Construction Grammar, all elements of linguistic form are represented within a heterogeneous lexicon that contains bound morphemes, free-standing content and function words, and complex phrase structures without terminal elements (e.g., the passive). This lexicon can be likened to a large municipal zoo, with many different kinds of animals. To be sure, the animals vary greatly in size, shape, food preference, life style, and the kind of handling they require. But they live together in one compound, under common management.

The remainder of this chapter is divided into three parts.

I. First, we will look at recent evidence on the relationship between lexical development and the emergence of grammar in normally developing children between 8-30 months of age. This will include longitudinal data from a group of normal infants followed across a crucial phase of language development. The evidence will show that the emergence and elaboration of grammar are highly dependent upon vocabulary size throughout this period, as children make the passage from first words to sentences and go on to gain productive control over the basic morphosyntactic structures of their native language.

II. Second, we will compare these results for normal children with studies of early language development in several atypical populations, including late and early talkers, children with focal brain injury, Williams Syndrome, Down Syndrome and Specific Language Impairment. Results will show that (a) grammar and vocabulary do not dissociate during the early stages of development in late talkers, early talkers or in children with focal brain injury, (b) grammatical development does not outstrip lexical growth at any point in development, even in the Williams population (a form of retardation in which linguistic abilities are surprisingly spared in the adult steady state), and (c) grammatical development can fall behind vocabulary in some subgroups (e.g., Down Syndrome. SLI), but this apparent dissociation can be explained by limits on auditory processing, without postulating isolated deficits in a separate grammar module.

III. Having reviewed the developmental findings in some detail, we will provide a brief critical review of evidence for and against the idea that grammar and the lexicon are mediated by separate neural systems in the adult brain. We will raise questions about the interpretation of differences in neural activity for grammatical and lexical stimuli in neural imaging studies of normal adults, and we will show that there is no solid evidence for a double dissociation between these putative modules in adult aphasia. This does not mean that all linguistic deficits are alike. Different <u>kinds</u> of lexical impairments have been observed (e.g., in fluent vs. nonfluent aphasic patients), and these lexical contrasts are typically accompanied by different <u>kinds</u> of grammatical breakdown. In other words, our municipal zoo can be damaged in a number of different ways. We will argue, however, that these diverse patterns can be explained within a unified lexicalist account.

We should note before proceeding that our arguments for the unity of grammar and the lexicon might be acceptable to Fodor (1983), who (unlike Chomsky) argues for a large and relatively undifferentiated language module, separate from the rest of cognition. However, the evidence presented below also suggests that the acquisition and neural representation of grammar and the lexicon are accomplished by domain-general mechanisms that transcend the boundaries of language proper, a conclusion that is incompatible with both the Fodorian and the Chomskian account.

I. Grammar and the lexicon in normally developing children

One of the nine criteria that define a "mental module" (Fodor, 1983) is the observance of a "characteristic maturational course." At first glance, it looks like the basic modules of 1960's generative linguistics emerge on a fixed and orderly schedule. Phonology make its first appearance in reduplicative babbling, between 6-8 months of age. Meaningful speech emerges some time between 10-12 months, on average, although word comprehension may begin a few weeks earlier. Vocabulary growth is typically very slow for the first 50-100 words, and many children spend between 4-8 months in what has come to be called the "one-word stage". Between 16-20 months, most children display a "burst" or acceleration in the rate of vocabulary growth, and first word combinations usually appear in between 18-20 months. At first, these combinations tend to be rather spare and telegraphic (at least in English). Somewhere between 24-30 months, most children show a kind of "second burst", a flowering of morphosyntax that Roger Brown (1973) has characterized as "the ivy coming in between the bricks." By 3-3.5 years of age, most normal children have mastered the basic morphological and syntactic structures of their language (defined by various criteria for productivity, including rule-like extension of grammatical structures to novel words). Hence one might characterize early language development as the successive maturation of separate modules for phonology, the lexicon, and grammar.

Of course this textbook story is not exactly the same in every language (Bates & Marchman, 1988; MacWhinney & Bates, 1989; Slobin, 1985, 1992, in press), and perfectly healthy children can vary markedly in rate and style of development through these milestones (Bates, Dale, & Thal, 1995; Fenson et al., 1994; Shore, 1995). At a global level, however, the passage from sounds to words to grammar appears to be a universal of child language development. A quick look at the relative timing and shape of growth in word comprehension, word production and grammar can be seen in Figure 4, taken from our own longitudinal study of language development from 8-30 months (Goodman, 1995). The word comprehension and production estimates are based on the same word checklist, and the grammar estimate is based on a 37-item scale for sentence complexity (note that these comprehension data were only collected from 8-16 months, and measurement of grammar did not begin until 16 months—see below for additional methodological details). Assuming for a moment that we have a right to compare the proportional growth of apples and oranges, this figure shows that all three domains follow a dramatic, nonlinear pattern of growth across this age range. However, the respective "zones of acceleration" for each domain are separated by many weeks or months.

Bickerton (1984) has taken this succession quite seriously. Following Chomsky[1], he argues that the period of babbling and single-word production prior to two years of age is essentially "pre-linguistic". True language only begins when sentences begin, around 2 years of age. Locke (1983, 1997) has argued for a similar discontinuity, albeit in a more subtle form. He suggests that the phase of single-word production (including some formulaic phrases like "I wan' dat" or "Love you") is governed by an "utterance collecting" mechanism that may be mediated primarily by the right hemisphere. The emergence of productive, lawful grammar between 2-3 years of age reflects the discontinuous emergence of a separate linguistic mechanism, possibly one that is mediated by the left hemisphere. Unlike Bickerton, Locke believes that there is a causal relationship between these two phases. Specifically, if the rule mechanism "turns on" before a critical mass of utterances has been stored, it will not operate properly. However, the two phases are mediated by distinct neural mechanisms, and each matures ("turns on") according to its own genetic timetable (i.e., vocabulary size does not "cause" the grammatical device to mature).

Is this passage from first words to grammar discontinuous, as Bickerton and Locke have proposed? We have known for some time that, within individual children, the content, style and patterning of first word combinations is strongly influenced by the content, style and patterning of single-word speech (Bates, Bretherton, & Snyder, 1988; Bloom, Lightbown, & Hood, 1975; Braine, 1976; Horgan, 1978, 1979, 1981). But of course no one has ever proposed that grammar can begin in the *absence* of words. As Locke notes, any rule-based device is going to have to have a certain amount of lexical material to work on. The real question is: Just how tight are the correlations between lexical and grammatical development in the second and third year of life? Are these components dissociable, and if so, to what extent? How much lexical material is needed to build a grammatical system? Can grammar get off the ground and go its separate way once a minimum number of words is reached (e.g., 50-100 words, the modal vocabulary size when first word combinations appear—Bates et al., 1988; Nelson, 1973; Shore, 1995; Shore, O'Connell, & Bates, 1984)? Or will we observe a constant and lawful interchange between lexical and grammatical development, of the sort that one would expect if the lexicalist approach to grammar is correct, and grammar does not dissociate from the lexicon at any point in life?

Our reading of the evidence suggests that the latter view is correct. As we shall see, the function that governs the relation between lexical and grammatical growth in this age range is so lawful that it approaches Fechner's law in elegance and power. The successive "bursts" that characterize vocabulary growth and the emergence of morphosyntax can be viewed as different phases of an immense nonlinear wave that starts in the single-word stage and crashes on the shores of grammar a year or so later.

Our first insights into this tight correlation came in a longitudinal study of 27 children who were observed at 10, 13, 20 and 28 months of age, using a combination of structured observations (at home and in the laboratory) and parental report (Bates et al., 1988; see also Bretherton, McNew, Snyder, & Bates, 1983; Snyder, Bates, & Bretherton, 1981). Among other things, we examined the concurrent and predictive relation between vocabulary size and grammatical status at 20 and 28 months of age. Vocabulary size was assessed with a combination of video observations and parental report (for a discussion of why parental report provides a faithful estimate of lexical size and content, see Bates et al., 1995; Fenson et al., 1994; Marchman & Bates, 1994). In this study, grammatical development was assessed in a rather standard fashion, calculating mean length of utterance in morphemes (MLU) from speech transcriptions, following the rules outlined by Brown (1973).[2] Table 1 summarizes the cross-lag correlations that we found between lexical and grammatical development within and across these two age levels. Results were very clear: The single best estimate of grammatical status at 28 months (right in the heart of the "grammar burst") is total vocabulary size at 20 months (measured right in the middle of the "vocabulary burst"). In fact, the correlation coefficient in this and related analyses with other grammatical variables hovered consistently between +.70 and +.84. Because we know that no measure can correlate with another variable higher than it correlates with itself (i.e., Spearman's Law of Reliability), it is interesting to note that separate samples of MLU at 28 months of age also tend to intercorrelate in the +.75 - +.80 range. What this means, in essence, is that 20-month vocabulary and 28-month MLU scores are statistically identical; one could be used as a stand-in for the other in predicting a child's rank within his/her group. Of course this kind of correlational finding does not force us to conclude that grammar and vocabulary growth are mediated by the same developmental mechanism. Correlation is not cause. At the very least, however, this powerful correlation suggests that the two have something important in common.

In a more recent series of studies, we have developed a new parental report instrument called the MacArthur Communicative Development Inventory (CDI) to study the relationship between lexical and grammatical development in a much larger sample of 1800 normally developing children, primarily middle class, all growing up in English-speaking households (see Bates et al., 1995; Bates, Marchman et al., 1994; Dale, 1991; Dale, Bates, Reznick, & Morisset, 1989; Fenson et al., 1993, 1994). The CDI relies primarily on a checklist format to assess word comprehension (from 8-16 months), word production (from 8-30 months) and the emergence of grammar (from 16-30 months). Numerous studies in many different laboratories have shown that these parental report indices provide a reliable and valid assessment of lexical development from 8-30 months (including both comprehension and production), and grammatical developments in the period from 16-30 months (see Fenson et al., 1994, for a review). Because these scales are published, and widely used in clinical and research settings, we refer the reader to other sources for methodological details.

The complete word production checklist in the CDI contains 680 words that are typically acquired by children exposed to American English before 30 months of age. It was much less obvious how to assess grammar through parent report, because the class of possible sentences is infinite. One solution was a checklist of 37 sentence pairs, each reflecting a single linguistic contrast that is known to come in across the 16-30-month period (e.g., "KITTY SLEEPING" paired with "KITTY IS SLEEPING"). Parents were asked to indicate which sentence in each pair "sounds more like the way that your child is talking right now," yielding scores that vary from 0 (no multiword speech at all) to 37 (the more complex form checked in every pair). Studies show that this measure correlates very highly with traditional laboratory measures of grammatical complexity (Dale, 1991; Dale et al., 1989), including correlations with MLU up to the statistical ceiling (i.e., as high as MLU correlates with itself in reliability studies). It is thus fair to conclude that these measures provide valid and reliable estimates of individual differences in grammatical development across the period from 16-30 months of age.

As reported by Fenson et al. (1994), the relationship between grammatical complexity and vocabulary size in their large cross-sectional sample replicates and extends the powerful grammar/vocabulary relationship that had emerged in Bates et al., (1988). Figure 5 (from Bates & Goodman, in press) illustrates the relation between performance on the 37-item sentence complexity scale with productive vocabulary size (collapsed over age, with children divided into groups reflecting fewer than 50 words, 50-100 words, 101-200 words, 201-300 words, 301-400 words, 401-500 words, 501-600 words and > 600 words). The linear correlation between these two measures is +.84 ($p < .0001$), but it is clear from Figure 5 that the function governing this relationship is nonlinear in nature.

Of course there is some individual variation around this function. This is illustrated by the standard error of the mean in Figure 5, and by the separate lines in Figure 6a, which indicate scores for children at the 10th, 25th, 50th, 75th and 90th percentiles for grammar within each vocabulary group. These variance statistics make two points: (1) individual differences around the grammar-on-vocabulary function are relatively small, and (2) the variance is consistent in magnitude at every point along the horizontal axis beyond 50-100 words. Both these points are clarified further if we compare the tight correlation between grammar and vocabulary with the clear dissociation between word comprehension and word production observed at an earlier point in language development. Figure 6b displays the relation between expressive vocabulary (on the vertical axis) and receptive vocabulary (on the horizontal axis), collapsed over age in children between 8-16 months (redrawn from the MacArthur norming study, Fenson et al., 1994). Analogous to Figure 6a, Figure 6b illustrates the relation between domains by plotting scores at the 10th, 25th, 50th, 75th and 90th percentile for word production within each comprehension group. What we see in Figure 6b is a classic fan-shaped pattern of variation, including children who are still producing virtually no meaningful speech at all despite receptive vocabularies of more than 200 words. Hence this figure captures a well-known phenomenon in the child language literature: Comprehension and production can dissociate to a remarkable degree. A certain level of word comprehension is prerequisite for expressive language to get off the ground, but comprehension (though necessary) is apparently not sufficient. If the same thing were true for the relationship between vocabulary and grammar, we would expect the same kind of fan-shaped variance in Figure 6a. That is, we might expect vocabulary size to place a ceiling on grammatical development up to somewhere between 50-200 words (when most children make the passage into multiword speech). After that point, the variance should spread outward as the two domains decouple and grammar takes off on its own course. Instead, we find that grammar and vocabulary are tightly coupled across the 16-30-month age range.

To understand the relevance of this finding, it is important to keep in mind that normally developing children are able to produce most of the basic morphosyntactic structures of their language by 3-3.5 years of age, including passives, relative clauses and other complex forms (Bates & Devescovi, 1989; Crain, 1991; Demuth, 1989; Marchman, Bates, Burkhardt, & Good, 1991; Slobin, 1985, 1992, in press). Hence the function in Figure 5 follows children right into the very heart of grammatical development, when productive control over crucial morphological and syntactic structures is well underway (Brown, 1973). We also note that this powerful function is not an artifact of age, because it remains very strong when age is partialled out of the correlation (Fenson et al., 1994). Indeed, age is a surprisingly poor predictor of both vocabulary and grammar within this 16-30-month window, for this large sample of healthy English-speaking children. Taken together, age and vocabulary size acount for 71.4% of the variance in grammatical complexity. When age is entered into the equation after vocabulary size is controlled, it adds a statistically reliable but exceedingly small 0.8% to the total variance accounted for. However, when vocabulary size is entered into the equation after age is controlled, it adds a reliable and robust 32.3% to the variance in grammar scores.

Given the power of this relationship, we might suspect that another kind of artifact is lurking beneath the surface. After all, the vocabulary checklist includes grammatical function words like prepositions, articles, auxiliary verbs, pronouns and conjunctions. Perhaps all that we really have in Figure 5 is a tautological relation of grammar with itself! To control for this possibility, we recalculated total vocabulary size for the full MacArthur sample, subtracting out grammatical function words for each individual child. Figure 7 illustrates the relation between grammar and vocabulary that is observed when vocabulary counts are based entirely on the remaining content words. The nonlinear function that remains is, if anything, even more powerful than the original function where all words are included in the vocabulary total.

The data that we have reported so far are all based on English. More recently, Caselli and Casadio (1995) have developed and normed a version of the MacArthur CDI for Italian. Although the word checklist for Italian is equivalent to the English list in length, it is not a mere translation; instead, the words listed within each category were selected specifically for Italian, based on prior studies of lexical and grammatical development in this language. Similarly, because the grammar of Italian is quite dissimilar from that of English, Caselli and Casadio constructed a 37-item sentence complexity scale designed to tap those structures that are known to develop in Italian between 16-30 months of age (Bates, 1976; Caselli, 1995; Cresti & Moneglia, 1995; Devescovi & Pizzuto, 1995; Pizzuto & Caselli, 1992; Volterra, 1976). Detailed cross-linguistic comparisons are provided elsewhere (Caselli, Casadio, & Bates, 1997; Caselli et al., 1995; Pizzuto & Caselli, 1994). For our purposes here, we note that the function linking grammar and vocabulary size is quite similar in English and Italian (Figure 8, from Caselli and Bates, 1996)—this despite striking differences between the two languages in the content of vocabulary and grammar.

Another possible objection to these findings revolves around the cross-sectional nature of the normative sample. Because the functions in Figures 4-8 are collapsed across different children at different age levels, we cannot assume that they represent patterns of growth for any individual child. In a more recent study (Goodman, 1995; Jahn-Samilo, 1995; Thal, Bates, Goodman, & Jahn-Samilo, in press), we have used the MacArthur CDI to follow individual children longitudinally, with parents filling out the forms on a monthly basis from 8 to 30 months of age. From 12-30 months, we also saw the children monthly in the laboratory, videotaping free speech and free play and administering structured measures of word comprehension, word production and comprehension of grammar. Thirty-four children enrolled in the study in the first few months, and 28 stayed with us through the 30-month end date. The sample was predominantly middle class, screened to exclude cases with serious medical complications (including mental retardation and prematurity). All children were growing up in homes in which English is the primary language spoken by both parents. Additional details about this sample and the cross-correlations between CDI and laboratory measures are available in Bates & Goodman (in press) and Jahn-Samilo, Goodman, Bates, & Appelbaum (1997). For present purposes, we note that the correlations between laboratory and parent report are very high in this sample, further evidence for the reliability and validity of the CDI as a measure of early grammar and vocabulary.

The finding that is most important for our purposes here regards the relationship between grammar and vocabulary in individual children followed across the 17-30-month period (that is, from the point at which we began to collect measures of grammatical abilities until the end of the study). Figure 9 compares the nonlinear function linking sentence complexity and vocabulary size in the respective cross-sectional and longitudinal samples. The two functions are remarkably similar, separated only by a very small lag (i.e., slightly lower complexity rates per vocabulary group in the longitudinal sample), well within the range of variation that we observe for the cross-sectional sample in Figures 5 and 6a.

Although this comparison does suggest that a common growth function is observed in both designs, we are still looking at group data in both cases (i.e., results collapsed over many different children at each data point). We might therefore ask whether the growth curves in the longitudinal study look similar for individual children, or whether the commonalities in Figure 9 represent group trends that mask sharp dissociations in at least some individual cases. To address this issue, we graphed the individual grammar-on-vocabulary functions for all 28 children. Results suggest a remarkable degree of similarity between these individual growth curves and the range of curves (from the 10th to the 90th percentile) summarized at the group level in Figure 6a (for details, see Bates & Goodman, in press).

We are convinced by these data that there is a powerful link between grammar and lexical growth in this age range, a nonlinear growth function that holds for both cross-sectional and longitudinal designs, at both the individual and the group level, and perhaps across languages as well (although two languages is a very small sample of the possibilities that the world has to offer). These results (even for individual children) are collapsed across a range of different grammatical structures. What does the relationship look like when we look at specific aspects of the grammar? Presumably, because we know that different grammatical structures come in at different points within this developmental window, we ought to expect individual forms to display different degrees and (perhaps) different types of "lexical dependence." For example, individual grammatical structures might require a different "critical mass" across the whole vocabulary, or they might require a critical number of lexical items within a specific class. Marchman & Bates (1994) have addressed this issue, using the MacArthur norming data to investigate the relationship between the number of verbs that children use and their progress on the verb morphology subscales on the CDI (i.e., the checklists of irregular, regular and overregularized forms noted above). They report a powerful nonlinear relationship between the number of verbs in the child's vocabulary (based on the subset of verbs that are used in the vocabulary checklist and in the past tense scale) and three forms of past tense marking: zero stem (the child is reported to use the verb in the citation form only), correct irregulars, and incorrect overgeneralizations. Results are similar to those observed in connectionist simulations of past tense learning (Rumelhart & McClelland, 1986; Plunkett & Marchman, 1991 & 1993), providing further evidence in favor of the idea that regular and irregular morphemes are acquired by the same learning mechanism, and tightly tied to the size and distribution of the child's verb vocabulary at any given point in development.

This demonstration of a link between verb vocabulary and past tense morphology is the only example we have right now of a link between specific grammatical structures and their requisite "critical mass" of lexical items. A great deal more work could be done in this area, to determine the lexical prerequisites (if any) for specific grammatical forms. Results of such investigations are likely to vary markedly within and across languages, despite the solid trends that we find by collapsing over lexical and grammatical types.

Explaining the link. Why is the relationship between grammar and the lexicon so strong in this period of development? In children who are developing on a normal schedule, the same basic nonlinear relationship appears in longitudinal and cross-sectional data, in at least two dramatically different languages, in different domains of grammar. The dependence of early grammar on vocabulary size is so strong and the nonlinear shape of this function is so regular that it approaches the status of a psychological law, akin to the reliable psychophysical functions that have been observed in perception (e.g., Weber's Law, Fechner's Law). But explanation by legislation is not very satisfactory, and it is particularly unsatisfactory if better explanations are available. We can offer five reasons why grammar and the lexicon are so closely related in this phase of development. None of these explanations are mutually exclusive.

(1) Perceptual bootstrapping. Nusbaum and Goodman (1994) and Nusbaum and Henly (1992) have proposed that efficient word perception requires a certain amount of top-down processing, permitting the listener to weed out inappropriate candidates from a large pool of items that overlap (at least partially) with the blurred word tokens that so often occur in fluent speech (see also Hurlburt & Goodman, 1992; Marslen-Wilson, 1987; McQueen, Cutler, Briscoe, & Norris, 1995). To the extent that this is true, it is probably even more true for the perception of grammatical function words and bound inflections. For a variety of reasons, these units are particularly hard to perceive (Cutler, 1993; Goodglass & Menn, 1985; Grosjean & Gee, 1987; Kean, 1977; Leonard, in press; Shillcock & Bard, 1993). They tend to be short and low in stress even in speech that is produced slowly and deliberately. In informal and rapid speech, speakers have a tendency to exploit the frequency and predictability of function words and bound morphemes by giving them short shrift, deforming their phonetic structure and blurring the boundaries between these morphemes and the words that surround them. In fact, when grammatical function words are clipped out of connected speech and presented in isolation, adult native speakers can recognize them no more than 40-50% of the time (Herron & Bates, in press). This is true of speech directed to children as well as speech directed to adults (Goodman, Nusbaum, Lee, & Broihier, 1990). Under these circumstances, we should not be surprised that young children are unable to acquire grammatical forms until they have a critical mass of content words, providing enough top-down structure to permit perception and learning of those closed-class items that occur to the right or left of "real words."

(2) Logical bootstrapping. Studies in several different languages have shown that verbs and adjectives are acquired later than nouns (Au, Dapretto, & Song, 1994; Caselli et al., 1995; Gentner, 1982; Pae, 1993; for a dissenting view, see Gopnik & Choi, 1990, 1995). Except for a few terms like "up" and "no" that can stand alone, function words tend to appear later still, well after the first verbs and adjectives appear (Bates, Marchman et al., 1994). Furthermore, many relatively early prepositions (e.g., "up") may not be used in the same way by children as by adults. Adults use them to specify a relation between objects or a location. Children on the other hand use them to refer to events (Smiley & Huttenlocher, 1995; Tomasello & Merriman, 1995) instead of using them as "grammatical glue." It has been suggested that this progression from names to predication to grammar is logically necessary, based on a simple assumption: Children cannot understand relational terms until they understand the things that these words relate. One can argue about the extent to which this assumption holds for individual structures, but it may provide a partial explanation for the dependence of grammar on lexical growth.

(3) Syntactic bootstrapping. The perceptual and logical bootstrapping accounts both presuppose that the causal link runs from lexical growth to grammar. However, studies from several different laboratories have shown that children between 1-3 years of age are able to exploit sentential information to learn about the meaning of a novel word (Goodman & McDonough, 1996; Goodman, McDonough, & Brown, 1996; Naigles, 1988, 1990; Naigles, Gleitman, & Gleitman, 1993; Sethuraman, Goldberg, & Goodman, 1996; Tomasello, 1992). Naigles et al. (1993) refer to this process as "syntactic bootstrapping", although it has been shown that children can use many different aspects of a sentence frame for this purpose, including sentence-level semantics, morphological cues, word order and prosody. It is therefore possible that the accelerating function in Figures 2-10 is due in part to the effect of the child's emerging grammar on lexical growth.

(4) Nonlinear dynamics of learning in a neural network. The above three accounts all support a link between lexical and grammatical development, but it is not obvious from these accounts why the function ought to take the nonlinear form that appears so reliably across populations and age levels. We noted earlier that the nonlinear functions governing the relation between verb vocabulary and the emergence of regular and irregular past tense marking appear in a similar form in English-speaking children and in neural network simulations of past tense learning (MacWhinney, Leinbach, Taraban, & McDonald, 1989; Marchman & Bates 1994; Plunkett & Marchman, 1991, 1993). This is only one example of a more general point: Multilayered neural networks produce an array of nonlinear growth functions, reflecting the nonlinear dynamics of learning and change in these systems (Elman et al., 1996, Chapter 4). The kinds of critical mass effects that we have proposed to underlie the relation between lexical and grammatical growth may be a special case of this more general approach to the nonlinear dynamics of learning (see also Port & van Gelder, 1995; Smith & Thelen, 1993; Thelen & Smith, 1994; van Geert, 1994).

(5) Lexically based grammar. Finally, as we noted at the outset of this paper, the historical trend in modern linguistics has been to place in the lexicon more and more of the work that was previously carried out in a separate grammatical component. The powerful relation between grammatical and lexical development that we have observed here is precisely what we would expect if grammar is an inherent part of the lexicon.

Points 1-4 all pertain to learning. Point 5 is a stronger claim, extending to the relationship between grammar and the lexicon in the adult steady state. The data that we have reviewed so far may be relevant only to the early stages of language development, the period in which the fundamental properties of language-specific morphosyntax are laid down. It is entirely possible that a modular distinction between grammar and the lexicon may emerge at a later point in development, in accordance with the processes of "modularization" described by Karmiloff-Smith (1992); see also Bates et al., 1988; Friederici, 1990). This question is best addressed by looking at the literature on language disorders in children and adults, where strong claims about the modularity of grammar and the lexicon have been made.

II. Grammatical development and the lexicon in atypical populations

As we shall see later, the literature on older children with Specific Language Impairment (SLI) and adults with language disorders gives us reason to expect selective impairments in early grammar. What happens in the early stages of development in children who are acquiring language on an atypical schedule? Are there any individual children or any specific pediatric population in which we can find a dissociation between early grammar and the lexicon, i.e., a deviation from the functions displayed in Figures 5-9?

Late and early talkers. If grammar and vocabulary really are separate modules, each maturing on a separate schedule, then it should be possible to locate at least a few individual children who are developing grammar at a normal rate, despite vocabulary scores that are abnormally high or low for their age. Thal and her colleagues have examined this issue within a larger program of research on late and early talkers. Later talkers are defined as children between 18-24 months who are in the bottom 10th percentile for expressive vocabulary, in the absence of retardation, frank neurological impairment, autism, deafness, or any other obvious biomedical cause for their delay (Bates et al.1995; Thal, 1991; Thal et al., in press; Thal & Katich, in press). Early talkers are defined, conversely, as children between 12-24 months who are in the top 10th percentile for expressive vocabulary (Robinson, Dale, & Landesman, 1990; Thal et al., in press; Thal, Bates, Zappia, & Oroz, 1996). To date, no evidence for such a dissociation between grammar and vocabulary has appeared in any of these samples. Instead, grammatical development appears to be tied to lexical level even in children at the far ends of the continuum.

To illustrate this point, we present the grammar-on-vocabulary functions for two individual children in Figure 11, for each session between 16 and 30 months (from Bates & Goodman, in press). These children were selected to represent extremes in rate of vocabulary growth, including one very late talker and one very early talker. The contrast between these two cases is particularly interesting for our purposes here, because there is absolutely no overlap in their vocabulary size across this longitudinal study from 17-30 months of age. Our late talker had a vocabulary of only 272 words on the CDI in the last session at 30 months. By contrast, our early talker already had a vocabulary of 315 words on the CDI at 17 months, when we began to administer the grammar scales. It is clear from Figure 11 that both children are making progress in grammar that is directly commensurate to their lexical abilities, even though they reach their respective grammar-on-vocabulary levels at widely different ages within this period of development.

Some further insights into this issue come from two case studies of children with extremely precocious language development (Thal & Bates, 1988; Thal et al., 1996). In one of these children, grammar does appear to lag behind vocabulary level, suggesting some degree of dissociation. However, a detailed comparison of the free speech data and parent report data reveals an unexpectedly strong association between vocabulary development and inflectional morphology for both these children, even though one of them has barely moved out of the single-word stage. Table 2 (from Thal et al., 1996) provides examples of the utterances produced by MW (17 months old with an expressive vocabulary of 596 words in the CDI) and SW (21 months old with an expressive vocabulary of 627 words on the CDI). With an MLU of 2.13, MW is right where we would expect her to be in grammar, given her vocabulary size (equivalent to performance by an average 28-30-month-old child in both domains). By contrast, SW has just begun to combine words (MLU 1.12) despite her huge vocabulary. In fact, her grammatical abilities are quite average for a 21-month-old child. However, the examples in Table 2 reveal a very curious phenomenon: production of words with contrasting inflections (e.g., "falling.....fell") in single-word utterances. Applying the criteria for morphological productivity developed by Brown (1973), Thal et al. discovered that both children have about as much control over English morphology as we would expect to find in a 2.5-year-old child. In fact, SW was actually more advanced than MW in grammatical morphology (i.e., productive control over more morphemes according to Brown's rules), and both children are well within the range of morphological development that we would expect for children with more than 500 words (Marchman & Bates, 1994). In other words, there is no dissociation between vocabulary size and grammatical morphology, although there is substantial variation in average utterance length. Thal et al. suggest that these two children differ primarily in the size of the unit that they are able to store in auditory memory, and/or the size of the unit that they are able to retrieve and reformulate in speech production (see also Peters, 1977). As we shall see shortly, this kind of processing account will prove useful in explaining the apparent dissociations observed in other clinical populations.

Early focal lesions. If there are separate neural mechanisms in the brain for grammar vs. the lexicon, then we might expect to find dissociations between these two aspects of language learning in children with congenital injuries to one side of the brain. Specifically, based on claims in the literature on adult aphasia (see below), we might expect to find greater delays in grammar among children with left frontal damage (including Broca's area), and greater lexical delays in children with left posterior damage (including Wernicke's area). Although these are reasonable predictions, there is virtually no evidence in their favor. When cases with intractable seizures or other medical complications are excluded, most studies of older children with a history of congenital brain injury report language abilities within the normal range, regardless of lesion side, size or site (for reviews, see Bates, Vicari, & Trauner, in press; Eisele & Aram, 1995; Vargha-Khadem, Isaacs, & Muter, 1994). As a group, these children do tend to perform below neurologically intact controls on many measures of language and cognition (including an average IQ difference of 3-10 points). However, they rarely qualify for a diagnosis of aphasia. Even more important, language outcomes are not reliably different for children with left- vs. right-hemisphere damage.

Some interesting exceptions to this general conclusion come from a handful of prospective studies that have looked at the first stages of language learning, before the plastic reorganization for which this population is famous has taken place. If we look early enough, we do find evidence for specific effects of lesion site—but these findings still do not map in any obvious way onto the adult aphasia literature, and they provide no evidence whatsoever for a dissociation between grammar and the lexicon. Some particularly relevant findings for our purposes here come from a series of studies by Bates et al. (in press) and Reilly, Bates and Marchman (in press), covering a period of development from 10 months to 12 years of age:

(1) **Absence of left/right differences.** There are few global differences between children with left- vs right-hemisphere injuries on expressive language measures across this range of development, in sharp contrast with more than a hundred years of research on brain injury in adults. There are also few differences in receptive language, except for a small but reliable disadvantage in word comprehension between 10-17 months in children with right hemisphere damage—the opposite of what we would predict based on the adult aphasia literature.

(2) **Surprising findings for Wernicke's area.** Differences in hemispheric specialization do emerge when one considers only those children who have injuries involving left temporal cortex, compared to children who have damage to any other sites in the right or left hemispheres. In particular, children with left temporal damage are selectively delayed in expressive language across the period from 10-60 months, on a succession of age-appropriate lexical <u>and</u> grammatical measures. This finding is surprising from the point of view of classical aphasiology, where lesions to left temporal cortex (the presumed site of Wernicke's area) are usually associated with fluent aphasia with mild to severe deficits in comprehension.

(3) **Surprising findings for Broca's area.** Bates et al. and Reilly et al. find no selective effects of damage to left frontal cortex (the presumed site of Broca's area) at any point from 10 months to 12 years of age. Frontal damage does make a difference in the period between 19-31 months, a period that includes dramatic changes in both lexical and grammatical development (i.e., the vocabulary burst and the emergence of grammatical morphology). However, this frontal effect is bilaterally symmetrical. That is, children whose lesions included <u>either</u> left frontal <u>or</u> right frontal cortex are more delayed in vocabulary size and in grammatical complexity. Putting these lines of evidence together, Bates et al. conclude that the temporal regions of the left hemisphere appear to be specialized in some way from the beginning of language learning, but the frontal regions of the left hemisphere do not have a special status until some point much later in normal development.

(4) **Disappearance of the left temporal effect.** After 5-7 years of age, children with a history of early focal brain injury tend (as a group) to perform below their age-matched normal controls on a range of lexical, grammatical and discourse measures (Reilly et al., in press). However, there are no effects due to side or site of lesion. In particular, the left temporal disadvantage observed in younger children is no longer detectable, suggesting that a great deal of reorganization must have occurred in the period between 1-6 years of age.

In addition to these group data, Bates et al. and Reilly et al. also find no evidence for a selective dissociation between grammar and lexical development in individual children. To illustrate this last point, Figure 12 shows the relationship between grammar and vocabulary for 19 individual children in the Bates et al. study, compared with the means for normal controls at different vocabulary levels between 19-31 months of age from the MacArthur CDI norming study (Fenson et al, 1994). We have plotted grammatical complexity against vocabulary size in this figure in a form that facilitates comparison between the focal lesion data and the other populations considered so far.[3] Separate symbols are provided to distinguish cases with left-hemisphere injuries involving the temporal lobe, left-hemisphere injuries that spare the temporal lobe, and right-hemisphere damage. The three lines in Figure 12 represent the 10th, 50th and 90th percentiles for grammar as a function of vocabulary size in the Fenson et al. normative sample. It should be clear from this figure that children with focal brain injury display the normal nonlinear relationship between grammar and vocabulary, even though some of them are markedly delayed on both (clustered in overlapping symbols in the bottom left quadrant). Of course there is some variance around this function, but the variance is no greater than we observe with normal children. 18 out of 19 focal lesion cases fall within the 10-90 window for normal children, and one falls outside; we would expect between 1-4 cases to fall outside that window if we were drawing children randomly from the normal population. In short, there is no evidence for a dissociation between vocabulary and grammar in this phase of development, even in children who have suffered pre- or perinatal injuries to the classical language zones within the left hemisphere.

Williams Syndrome and Down Syndrome. Williams Syndrome (WMS) and Down Syndrome (DNS) are genetically based forms of mental retardation. In both groups, mean IQs generally hover between 40-60, although a broader range of IQ scores can be observed at every stage from infancy through adulthood. Despite similarities in global IQ and in life experience, recent studies have revealed sharp contrasts between the two groups. For our purposes here, we are particularly interested in the claim that WMS and DNS represent a double dissociation between lexical and grammatical aspects of language processing.

Children with DNS are markedly delayed in the acquisition of language. More importantly, their language abilities at virtually every stage (including the adult steady state) fall *below* the levels that we would expect based upon their mental age (Chapman, 1995; Miller, 1987, in press a&b). Furthermore, children and adults with DNS appear to be especially impaired in the production of bound and free grammatical morphemes, constituting a form of congenital agrammatism that is even more severe than the selective delays in grammatical morphology reported for children with Specific Language Impairment (see below). The function word omissions and structural simplifications produced by older children with DNS are especially salient in a richly inflected language like Italian (Contardi & Vicari, 1994).

By contrast, older children and adults with WMS display levels of linguistic knowledge and language use that are surprisingly good when they are compared with the low levels of performance that the same individuals show on most measures of visual-spatial cognition, problem-solving and reasoning (Bellugi, Bihrle, Neville, Jernigan, & Doherty, 1992; Karmiloff-Smith, Klima, Bellugi, Grant, & Baron-Cohen, 1995; Mervis & Bertrand, 1993). This does not mean that individuals with WMS are "language savants." Those studies that have used normal controls have shown that the linguistic performance of WMS falls invariably below their *chronological age* — which is, of course, not surprising for subjects with an IQ score around 50. When WMS are compared with younger normals matched for *mental age*, the picture is mixed. Some studies report performance above mental-age controls on a handful of measures (including phonological memory and acquisition of novel words), but most studies report performance close to mental age on tests of vocabulary comprehension, sentence comprehension, sentence repetition and spontaneous sentence production (Capirci, Sabbadini, & Volterra, in press; Giannotti & Vicari, 1994; Vicari, Brizzolara, Carlesimo, Pezzini, & Volterra, in press; Volterra, Pezzini, Sabbadini, Capirci, & Vicari, in press). For present purposes, the point is that older individuals with WMS and DNS differ markedly in their control over language, particularly grammatical morphology. In view of these differences, a number of studies have begun to explore the early stages of language development in WMS and DNS. When do these two groups separate? Is the emergence of syntax dissociated from vocabulary development for either the WMS or the DNS group at any point in development?

In fact, studies suggest that both groups are severely and equally delayed on early language milestones (Mervis & Bertrand, 1993; Thal, Bates, & Bellugi, 1989). In other words, despite their ultimate proficiency with language, children with WMS are late talkers. This conclusion is underscored in a recent study by Singer, Bellugi, Bates, Rossen, & Jones (in press), who used the MacArthur CDI to obtain early language data from a large sample of children with WMS or DNS between one and six years of age. In the period of development covered by the infant scale (equivalent to normal children between 8-16 months), WMS and DNS were equally and severely delayed in both word comprehension and word production. The predicted separation between WMS and DNS did not emerge until the period of development covered by the toddler scale (equivalent to normal children between 16-30 months). Both groups were still delayed by approximately two years at this point, with no significant difference in overall vocabulary size. However, Singer et al. found striking differences in the emergence of grammar. Interestingly, this difference reflects a *DNS disadvantage* rather than a *WMS advantage*. To facilitate comparison across groups, we have plotted the data for individual WMS and DNS from Singer et al. in Figure 13, in the same format adapted throughout this chapter. Within WMS, grammatical development appears to be paced by vocabulary size, in the normal fashion. In fact, when these children are compared with lexically matched normal controls from the CDI sample, the relationship between grammar and vocabulary size is identical, following the same nonlinear accelerating function described above for normals and for children with focal brain injury. In short, there is no evidence for a dissociation between grammatical and lexical development in WMS — at least not in this early phase of grammatical development. By contrast, the DNS sample provides our best evidence to date for a significant dissociation between grammar and the lexicon. In particular, DNS children scored significantly *below* the grammatical levels displayed by normal children and by WMS matched for vocabulary size (Figure 13).

Note that this finding for DNS constitutes our first evidence so far for a dissociation between grammar and lexical development. Singer et al. conclude that lexical size is a necessary but not sufficient condition for the acquisition of grammatical function words, the onset of word combinations, and growth in sentence complexity. This finding is compatible with reports on the selective impairment of grammar displayed by older DNS, although the basis of the impairment is still unknown. Of course it could be due to impairment of some domain-specific grammatical processor (e.g., Pinker, 1991). Alternatively, it may derive from aspects of information processing that are only indirectly related to grammar. Wang & Bellugi (1994) have reported a double dissociation in these two groups between auditory short-term memory (significantly better in WMS) and visual short-term memory (significantly better in DNS). It appears that DNS suffer from a selective impairment in one or more aspects of auditory processing, a deficit that is superimposed upon their more general cognitive delay. Under these circumstances, it is perhaps not surprising the DNS are selectively impaired in the ability to detect, store and/or retrieve those aspects of their linguistic input that are lowest in phonological salience (as Leonard, Bortolini, Caselli, McGregor, & Sabbadini, 1992, have reported for children with SLI) and lowest in visual imagery (as Goodglass & Menn, 1985, have reported for adults with Broca's aphasia). This brings us to a consideration of grammatical deficits in older children.

Specific Language Impairment. SLI is defined as a delay in expressive language abilities that is at least 1 standard deviation below the mean for the child's chronological age, in the absence of mental retardation, frank neurological impairment, social-emotional disorders (e.g., autism), or any other serious biomedical risk factors that could account for the delay. A diagnosis of SLI is usually given only after 3-4 years of age, beyond the period in development that we have considered so far. To some extent, research on this population does support the notion that grammar can dissociate from lexical (and cognitive) abilities. However, as we have already seen in the case of Down Syndrome, it may be possible to explain this dissociation on perceptual grounds.

There is general agreement about the nature of the language impairment in SLI. However, there is considerable disagreement about its cause, and even more controversy regarding its specificity (i.e., whether the deficit really is restricted to language). After 30 years of research looking for deviant patterns of language development, most investigators in this field have concluded the SLI represents a pattern of delay rather than deviance (for recent reviews, see Leonard, in press; Bishop, in press). That is, within every linguistic domain that has been studied to date, the expressive and/or receptive abilities of children with SLI are qualitatively similar to those of younger normal children. However, a specific kind of deviance can be detected if one looks across rather than within linguistic domains (Johnston & Schery, 1976). In particular, grammatical morphology appears to be more delayed than any other area of language development. Thus much of the debate in this field concerning the nature and causes of SLI revolves around the disproportionate problems that children with SLI experience in this aspect of grammar, with some investigators arguing that the deficit is due to a problem that is strictly linguistic in nature (Clahsen, 1991; Gopnik & Crago, 1991; Rice, 1996; van der Lely, 1994), while others argue that the morphological problems observed in SLI are secondary to processing deficits that may transcend the boundaries of language (Leonard, in press; Bishop, in press; Tallal et al., 1996).

By definition, the term "specific language impairment" implies a deficit that is restricted entirely to language. However, some investigators report that children with SLI score significantly below age-matched controls on at least some nonlinguistic measures, including mental imagery and mental rotation (Johnston, 1994), symbolic play (Thal & Katich, in press), and shifting attention (Townsend, Wulfeck, Nichols, & Koch, 1995). Tallal and her associates have proposed that the specific vulnerability of morphology is a by-product of a subtle deficit in the ability to perceive rapid temporal sequences of auditory stimuli (Tallal et al., 1996; Tallal, Stark, & Mellits, 1985). Leonard (in press) and Bishop (in press) agree with this proposal in spirit, although they have argued for a perceptual deficit that involves degree of internal detail (e.g., spectral features) as well as temporal resolution. There has been strong resistance to Tallal's proposal among investigators like Mody, Studdert-Kennedy and Brady (1997), who propose that the basis of congenital language impairment (particularly the impairments resulting in dyslexia) is phonological rather than acoustic in nature. In fact, the phonological and acoustic proposals are not mutually exclusive: if one takes a developmental perspective, it is clear that an acoustic deficit could result in incomplete and faulty phonological learning, with consequences for the ability to segment and acquire phonologically weak elements of grammatical morphology. Furthermore, it has been shown that degradations at the phonetic level lead to a reduction in semantic activation even in normal adults (Utman, 1997). Hence, an initial deficit at the perceptual level could create a cascade of deficits at higher levels of language processing, even though children do make progress and learning does occur. The fact that children with Down Syndrome and children with SLI both experience a selective deficit in the use of grammatical morphology is compatible with this account. This brings us at last to a consideration of the case for and against a modular dissociation between grammar and the lexicon in adults.

III. Grammar and the Lexicon in the Adult Brain

The evidence reviewed so far on the interdependence of lexical and grammatical development is compatible with a unified lexicalist approach to grammar. However, it is at least possible that a modular dissociation between grammar and the lexicon emerges over time, a "modularization" process (Karmiloff-Smith, 1992) that is the outcome rather than the cause of development. We will end this chapter with a necessarily brief consideration of the claim that grammar and the lexicon are mediated by distinct neural systems in the adult brain, an hypothesis that is compatible with our developmental findings but would not be compatible with a unified lexicalist account of grammar in the adult steady state.

Two kinds of evidence are relevant to this claim: neural imaging studies of grammatical and lexical processing in normal adults, and dissociations between grammar and the lexicon in patients with focal brain injury. To evaluate this evidence, we need to keep the following points in mind.

1. All knowledge is in the brain. Where else would it be? Even if we could show that a given class of stimuli is correlated with specific patterns of neural activity in normals, and/or with specific lesion sites in aphasics, we cannot conclude anything about the source of that knowledge, i.e., whether it is innate, acquired, or an emergent property of interactions at many levels. If we could demonstrate that a specific pattern of neural mediation is present at birth, prior to any experience with the stimuli in question, we might be justified in concluding that this pattern is innate. This does not appear to be the case for grammar and the lexicon in children with focal brain injury (see above).

2. Any difference in experience and/or behavior must be accompanied by differences in neural activity. This is a logical consequence of (1): If an individual responds differently to two classes of stimuli, then these two classes *must* be associated with different patterns of activity in the brain (whether or not we are able to detect those differences with current technology is a separate question). There are, for example, recent demonstrations of differences in brain activity for content vs. function words (Nobre & Plunkett, 1997), regular vs. irregular morphemes (Jaeger et al., 1996), grammatical violations vs. lexical violations (Osterhout & Holcomb, 1993). There are also demonstrations of differences in brain activity for high- vs. low-frequency words (Indefrey et al., 1997), nouns vs. verbs (Nobre & Plunkett, 1997), tool words vs. animal words (Martin, Wiggs, Ungerleider, & Haxby, 1996). None of these demonstrations are sufficient to establish the existence of separate brain systems. If every difference in neural activity is interpreted as a difference in kind, then we would have to postulate separate brain systems for chess, for English spelling, for high- vs. low-frequency words—n short, for just about every systematic distinction between classes of stimuli .

3. Localization and domain specificity are not the same thing. Even if we could show that a given brain region is correlated with a specific kind of processing from the beginning of life, we could not conclude (without further evidence) that the pattern is domain-specific, i.e., that the neural region in question is dedicated to that class of stimuli and no other. It has been shown, for example, that every single component of the complex called Broca's area shows significant activation during one or more nonverbal motor planning tasks (Erhard, Kato, Strick, & Ugurbil, 1996). Is Broca's area involved in speech? Yes. Is Broca's area unique to speech? No. The same argument applies to demonstrations of a neural difference between grammatical and lexical violations, content words vs. function words, nouns vs. verbs, tool words vs. animal words. Such differences could reflect differences in the kind of processing required (e.g., high demands on memory for stimuli that are long, or low in imageability; high demands on perception and attention for stimuli that are short and low in acoustic salience), rather than a modular parcellation of the brain for specific kinds of content.

In our view, the burgeoning literature on lexical and grammatical processing using event-related brain potentials (ERP), positron emission tomography (PET) or functional magnetic resonance imaging (fMRI) reflects confounds along all these dimensions. There are indeed some demonstrations that grammatical and lexical stimuli lead to different patterns of brain activity. However, findings are quite variable from one study to another (reflecting variations in task, stimuli and instructions), providing little evidence for separate, domain-specific neural systems for grammar vs. the lexicon.

A more interesting challenge comes from the adult aphasia literature, where some strong claims about the dissociability of grammar and semantics have been made (Kean (Ed.), 1985; Grodzinsky (Ed.), 1993). Briefly, it has been argued that nonfluent Broca's aphasia constitutes a form of "central agrammatism", a specific difficulty with grammatical processing that shows up in all modalities, including agrammatic speech (syntactically simplified, with few inflections or function words) and receptive agrammatism (difficulty processing sentences like "The boy who chased the girl is tall", in which the patient cannot rely on semantic or pragmatic information). Because Broca's aphasia is correlated with damage to the inferior frontal region of the left hemisphere (especially Broca's area), some have concluded that Broca's area stands at the center of a specific neural system for grammar. This position is illustrated in the following quote from Zurif & Caramazza (1976, p. 270):

"The particular effects of anterior brain damage are not limited to speech; nor are these effects due to an economy of effort. Rather, *at no level* does the agrammatic patient appear fully capable of processing the small words of language, epecially those words that function as syntactic markers for implicit grammatical structure." (italics ours)

Although this was a promising hypothesis through the 1970's and 1980's, most aphasiologists have now abandoned the doctrine of central agrammatism in favor of a position in which the same deficits are explained with reference to more general processing deficits that transcend the boundaries of grammar. This change in position is illustrated in the following quote from Zurif, Swinney, Prather, Solomon, and Bushell (1993, p. 462):

"The brain region implicated in Broca's aphasia is *not* the locus of syntactic representations *per se*. Rather, we suggest that this region provides processing resources that sustain one or more of the fixed operating characteristics of the lexical processing system—characteristics that are, in turn, necessary for building syntactic representations in real time."

The reasons for this sea change are complex, and have been reviewed in some detail elsewhere (Bates & Goodman, in press; Bates & Wulfeck, 1989; Bates, Wulfeck, & MacWhinney, 1991; Blackwell & Bates, 1995; Devescovi et al., 1997; see also Menn & Obler, 1990). We will restrict ourselves here to a brief summary of arguments against a lexical/grammatical dissociation and the separate neural system for grammar that such a dissociation seemed to require.

(1) All aphasic patients have lexical deficits. Anomia refers to a deficit in word retrieval. Although many different forms of anomia have been described, one fact is very clear: Anomia is reported in every form of aphasia, including the nonfluent agrammatic syndrome associated with lesions to Broca's area. This point is illustrated in Table 3, which provides a classical taxonomy of the seven major aphasia subtypes. Despite ample variation in comprehension, fluency and repetition, anomia is observed in all seven subgroups. Simply put, this means that there is no evidence of a full double dissociation between grammar and the lexicon. Grammatical deficits are always accompanied by at least some form of anomia.

(2) Agrammatic patients still "know" their grammar. Starting the 1980's, a series of studies have shown that so-called agrammatic patients can perform above chance on grammaticality judgment tasks, including some very subtle morphosyntactic judgments (Linebarger, Schwartz & Saffran, 1983; Shankweiler, Crain, Gorrell, & Tuller, 1989; Wulfeck, 1988; Wulfeck, Bates, & Capasso, 1991). These studies are complemented by a growing cross-linguistic literature showing that agrammatic patients retain language-specific profiles in their performance on both expressive and receptive tasks (Bates et al., 1991; Menn & Obler, 1990), suggesting that their performance is still governed (in considerable detail) by language-specific grammatical knowledge.

(3) Expressive agrammatism is not specific to any syndrome. The idea that grammar is impaired in Broca's aphasia but preserved in fluent patients with Wernicke's aphasia was proposed in the 1970's, based almost exclusively on data for English-speaking patients. In fact, it has been known for almost 100 years that Wernicke's aphasics also display grammatical deficits (Pick, 1913/1973). However, these deficits are only apparent in richly inflected languages. As Pick noted (based on his own research with German and Czech patients), non-fluent patients tend to err by omitting inflections and function words ("agrammatism"), while fluent patients err by producing the wrong inflection or function word ("paragrammatism"). Because English has so little inflectional morphology (and because function word substitution errors are multiply interpretable), there are few opportunities to observe frank paragrammatic symptoms. Hence the belief that expressive agrammatism is restricted to Broca's aphasia is a by-product of research conducted in English! Table 4 (adapted from Goodman & Bates, in press) presents a summary of populations who are known to display some form of expressive agrammatism, including some of the congenital populations that we have already described (Down Syndrome, Williams Syndrome, SLI). At least three different forms of expressive agrammatism have been reported: the nonfluent variety, characterized by omission (a predominant symptom in Broca's aphasia, Down Syndrome, and SLI), the fluent or hyperfluent variety, characterized by substitution and occasional inappropriate additions (a predominant symptom in Wernicke's aphasia, Italian children with Williams Syndrome, and the spoken and written language of some congenitally deaf adults), and a third variety that we have called "syntactic simplification," characterized by a reduction in the use of complex syntactic forms in the absence of frank errors of omission or substitution (a symptom that has been reported in Alzheimer's disease, and in normal aging). For present purposes, the key point is that expressive agrammatism is not restricted to any specific clinical group, nor is it associated uniquely with damage to any particular region of the brain.

(4) Patients display similar grammatical and lexical symptoms. Table 4 also summarizes the lexical symptoms that are characteristic of each patient group. Although this is an idealization (most patients display more than one symptom type), a characterization of patients by their predominant lexical and grammatical symptom reveals some striking similarities. For example, patients who display an omission pattern in grammar tend to produce lexical omissions as well (i.e., complete word-finding failures). This is particularly true of Broca's aphasics, but a similar pattern can be detected in the underproduction of content words reported for Down Syndrome and SLI. Patients who display a substitution pattern in grammar tend to produce lexical substitutions as well (referred to as semantic paraphasias). This is particularly true for Wernicke's aphasics, but similar phenomena have been reported in Williams Syndrome. The one dissociation here involves the congenitally deaf, who reportedly do make grammatical substitutions and additions in the absence of frank lexical paraphasias. Finally, those individuals who produce a reduced and restricted range of syntactic forms in the absence of frank grammatical errors also have a tendency to overproduce pronouns, light verbs (e.g., "make" and "do") and other under-specified lexical forms, in the absence of frank lexical errors. This joint lexical/grammatical pattern has been reported in Alzheimer's disease and in studies of language production in normal aging. Taken together, these results suggest that grammatical and lexical deficits have a common cause, compatible with the heterogeneous but unified lexicalist approach to grammar described in the introduction.

(5) Receptive agrammatism is not specific to any syndrome, and can be observed in normals under stress. Finally, it is now quite clear that the profiles of receptive agrammatism reported for Broca's aphasics are not unique to patients with left anterior lesions, and can be observed in a host of different populations including normals processing language under stress. Receptive agrammatism is characterized by a marked difficulty in processing inflections and closed-class words, together with the reduction or loss of the ability to process noncanonical word order types (e.g., passives like "Tom is kissed by Mary" are harder than actives like "Tom kisses Mary"; object relatives like "It's the boy that the girl kisses" are harder than subject relatives like "It's the boy that kisses the girl." Table 5 (adapted from Bates & Goodman, in press) summarizes the populations in which these two receptive symptoms have been observed. Simply put, the same elements that are difficult for Broca's aphasics are difficult for everybody! The same specific profiles of morphological vulnerability observed in Broca's aphasia (e.g., difficulty detecting agreement errors despite preserved ability to detect word order errors) are observed in a wide range of patient groups, and in normal college students who are asked to process the same stimuli under perceptual degradation (e.g., a partial noise mask), temporal degradation (compressed speech) or cognitive overload (e.g., digit load). A similar story holds for complex noncanonical sentence structures, with one interesting exception. For Broca's aphasics, Wernicke's aphasics, even anomic aphasics with no history of expressive agrammatism, it is invariably the case that active sentences and subject relatives elicit more accurate performance than passive sentences or object relatives. This same order of difficulty is observed in normals as well, albeit at a much higher accuracy level, and it is exaggerated in the aphasic direction when college students are forced to process the same sentence stimuli under a noise mask or with compressed speech. However, in contrast with results for grammatical morphemes, the two "hard" sentence structures appear to be resistant to the effects of a cognitive overload: Subjects in a dual-task condition perform no worse than subjects with processing under ideal conditions. This is our first evidence to date that the effect of generic stressors on normal processing is different depending on the kind of morphosyntactic structure that subjects are required to process. This is an interesting result, but the general message is the same: Receptive agrammatism is not unique to any form of aphasia, and may reflect "weak links in the processing chain" that show up in neurologically intact individuals under adverse processing conditions.

Putting these lines of evidence together, we conclude that there is no compelling evidence for a "hard" dissociation between grammar and the lexicon, and hence no evidence for the claim that grammar and the lexicon are mediated by separate, dedicated, domain-specific neural systems. This does not mean that grammar doesn't exist (it does), or that grammatical and lexical structures are identical (they are not). As we have already noted, we should expect different classes of stimuli to elicit different patterns of brain activity, depending on the task, the specific nature of the stimuli, and the kind of processing that each requires. Big and small, short and long, loud and soft, frequent and rare—any systematic difference in stimulus characteristics may require a different configuration of processors. The brain, like the hand, is a flexible and dynamic system that responds with exquisite precision to the demand characteristics of the task and the object to be manipulated. The human brain is the only system on earth that is capable of acquiring a fully grammaticized language. It is also the only system capable of musical composition, ice hockey and international finance. The mix of systems that has evolved to make these accomplishments possible is still unknown, but one thing is certain: There is (at this writing) no evidence that requires postulation of a mental organ for grammar. The emergentist account of grammar is viable, and is, in our view, the most coherent and parsimonious account that is currently available.

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FOOTNOTES

"Observation of early stages of language acquisition may be quite misleading in this regard. It is possible that at an early stage there is use of languagelike expressions, but outside the framework imposed, at a later stage of intellectual maturation, by the faculty of language—much as a dog can be trained to respond to certain commands, though we would not conclude, from this, that it is using language." (Noam Chomsky, *Reflections on language* (p.53). New York, Pantheon Books, 1975).

We also looked at many other metrics of grammatical development, including propositional complexity and morphological productivity. After all that work we were surprised to find that, at least in this period of development, MLU is so highly correlated with other, more sophisticated measures, that there was no point in using any other estimate of grammar in correlational analyses with other variables; for a discussion of this point, see Bates et al., 1988.

Bates et al. described the relation between vocabulary and grammar using the CDI subscale on which parents record the three longest utterances their children have produced in the last two weeks. Scores on the 37-item complexity scale were only available for children from 2 of the 3 research sites participating in that study. For our purposes here, we have used the 37-item complexity scale data, available only for the San Diego and New York populations. In addition, we excluded data for one child who was dropped from the focal lesion sample one year after the Bates et al. study, due to extraneous medical complications. Despite these differences, the results in Figure 12 for 19 children on the complexity scale are comparable to the results reported by Bates et al. for 30 children on the longest-utterance scale.

TABLE 1:
RELATIONS BETWEEN GRAMMATICAL DEVELOPMENT AND VOCABULARY SIZE FROM 20 TO 28 MONTHS
(From Bates, Bretherton & Snyder, 1988)

	20-Month Vocabulary	20-Month MLU[1]	28-Month Vocabulary	28-Month MLU[1]
20-Month Vocabulary	------			
20-Month MLU[1]	+.54**	------		
28-Month Vocabulary	+.64**	+.47*	------	
28-Month MLU[1]	+.83**	+.48*	+.73**	------

* $p < .05$ ** $p < .01$

[1]Mean Length of Utterance in Morphemes

TABLE 2: EXAMPLES OF LANGUAGE PRODUCTION BY TWO VERY EARLY TALKERS (from Thal, Bates, Zappia, & Oroz, 1996)

MW:		**SW:**	
Age:	17 Months Old	Age:	21 Months Old
Vocabulary	596 words	Vocabulary:	627 words
Vocabulary age:	30 months	Vocabulary age:	> 30 months
MLU:	2.13	MLU	1.19
MLU age:	28 months	MLU age:	20 months

MW:

Where cup went?
Where chair went?
Teddy bear went?
Baby doing?

Wanna walk e baby.
Wanna put it on.
Wanna go ride it.
Want mom get off.

Daddy take her. (referring to self)
Help with the apple.

Can't get the teddy bear.
Teddybear the bath.

Too much carrots on the dish.

Move it around.
Clean e bottom.

Put ne sofa.
Put in eye.

Mommy wear hat.
Mommy smell it.
Mommy read the book.
Mommy sit down.

Find Becky.
See Becky in the morning.
Becky is nice.
Saw Becky and goats.

SW:

Pretty.
Cute.
Big.
Round.
Dry.
Hungry.
Wet.
Different.
Enough.
Else.
More.
Minute.

Brushing.
Hiding.
Baby crying.

Hold.
Hold it.
Dropped it.
Bring it.

Falling.
Fell.

Talk.
Talking.

Wash'em.
Shirt on.
Teddy up.
Mommy shoe.

TABLE 3: TRADITIONAL APHASIA CLASSIFICATIONS

APHASIA TYPE	Production: Naming	Production: Fluency	Comprehension ("bedside")	Repetition
Broca	-	-	+	-
Wernicke	-	+	-	-
Transcortical Motor	-	-	+	+
Transcortical Sensory	-	+	–	+
Conduction	-	+	+	-
Anomia	-	+	+	+
Global	-	-	-	-

TABLE 4: VARIETIES OF EXPRESSIVE AGRAMMATISM AND THEIR RELATION TO LEXICAL SYMPTOMS
(adapted from Bates & Goodman, in press)

GROUP	PREDOMINANT GRAMMATICAL SYMPTOM	PREDOMINANT LEXICAL SYMPTOM
Broca's aphasia	omission of function words & inflections	word finding failure
Specific Language Impairment	omission of function words & inflections	word finding failure
Down Syndrome	omission of function words & inflections	word finding failure
Wernicke's aphasia	substitution of function words & inflections	word substitutions (paraphasia)
Williams Syndrome	substitution of function words & inflections	word substitutions (paraphasia)
Neurologically intact deaf speakers of an oral language	substitutions, additions of function words	??
Anomic aphasia	reduction in syntactic complexity without frank errors of omission or substitution	empty speech (heavy use of pronouns and "light forms")
Alzheimer's dementia	reduction in syntactic complexity without frank errors of omission or substitution	empty speech (heavy use of pronouns and "light forms")
Normal aging	reduction in syntactic complexity without frank errors of omission or substitution	empty speech (heavy use of pronouns and "light forms")

TABLE 5: VARIETIES OF RECEPTIVE AGRAMMATISM ACROSS POPULATIONS
(adapted from Bates & Goodman, in press)

GROUP	DIFFICULTY PROCESSING CLOSED-CLASS MORPHEMES	DIFFICULTY PROCESSING RARE AND/OR COMPLEX SYNTACTIC FRAMES
Broca's aphasia	XX	XX
Wernicke's aphasia	XX	XX
Anomic aphasia	X	X
Alzheimer's dementia	~	X
Neurologically intact deaf speakers of an oral language	X	~
Specific Language Impairment	X	X
Down Syndrome	X	X
Williams Syndrome	X	X
Elderly controls and non-aphasic patients	~	~
College students under perceptual degradation (noise or compression)	~	~
College students under cognitive overload (dual-task conditions)	~	no deficit

XX = severe deficit
X = moderate deficit (worse than age- and/or IQ-matched normal controls)
~ = mild deficit (worse than normal young adults)

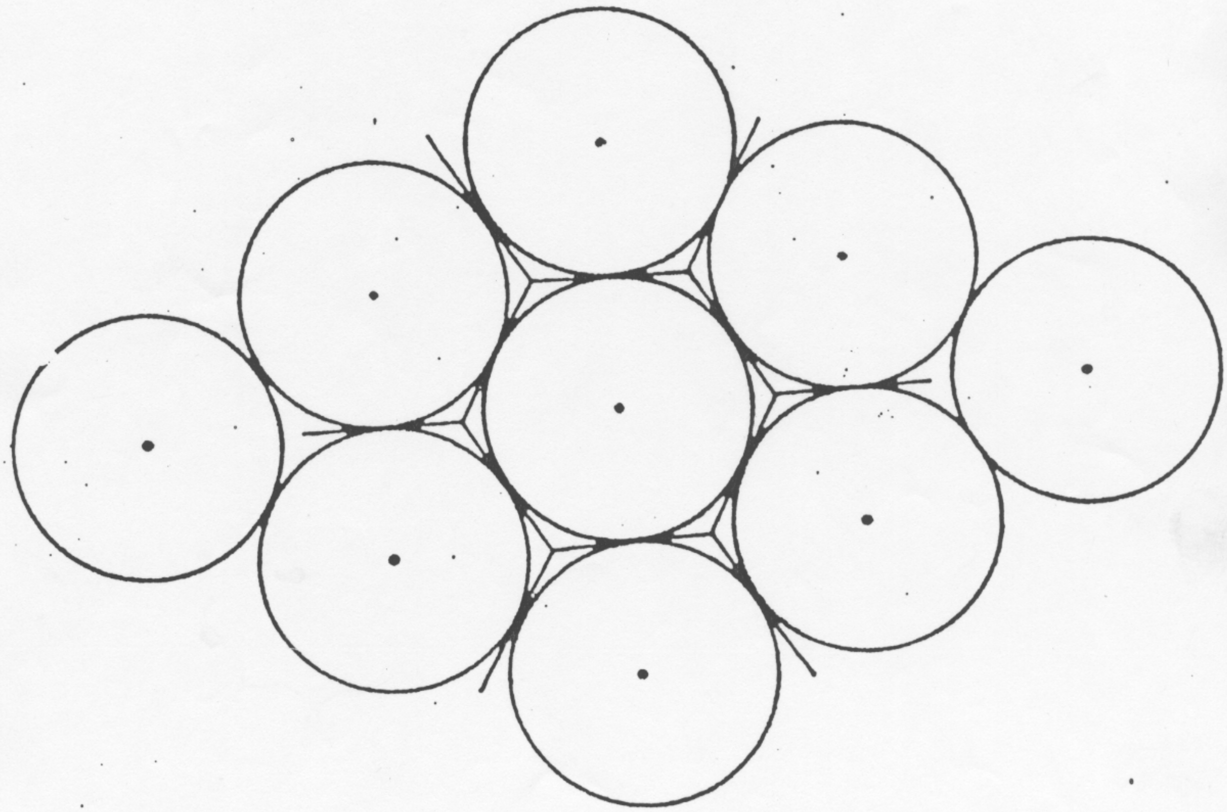


Figure 1 Diagram of hexagonal cells. After Bonanni.

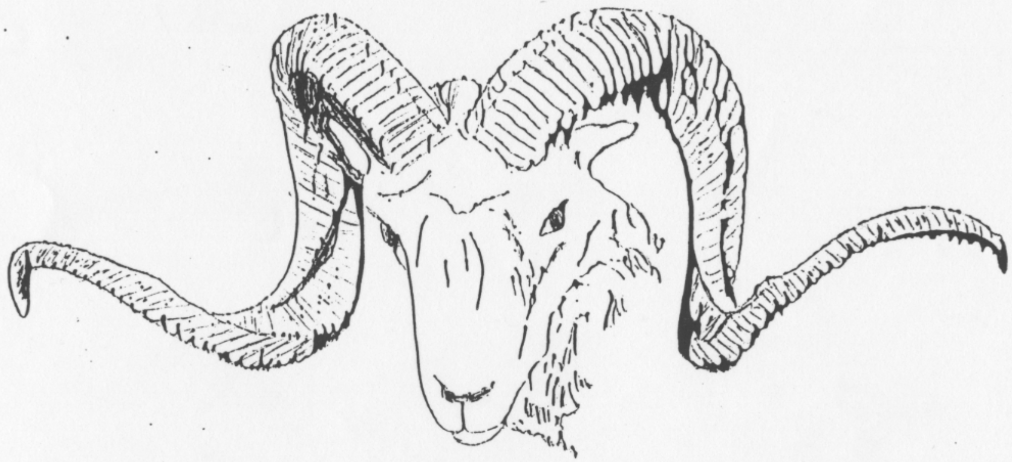


Fig. 2. Marco Polo's sheep: *Ovis poli*. From Cook.

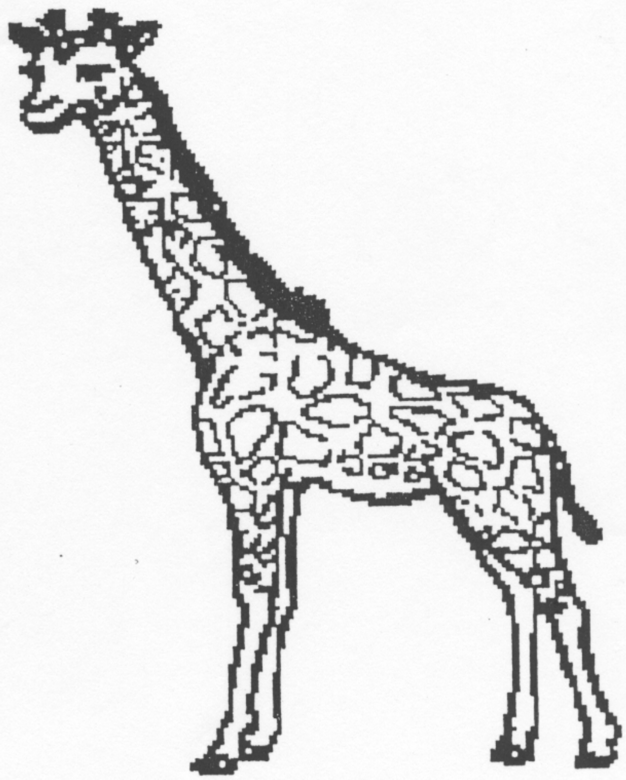
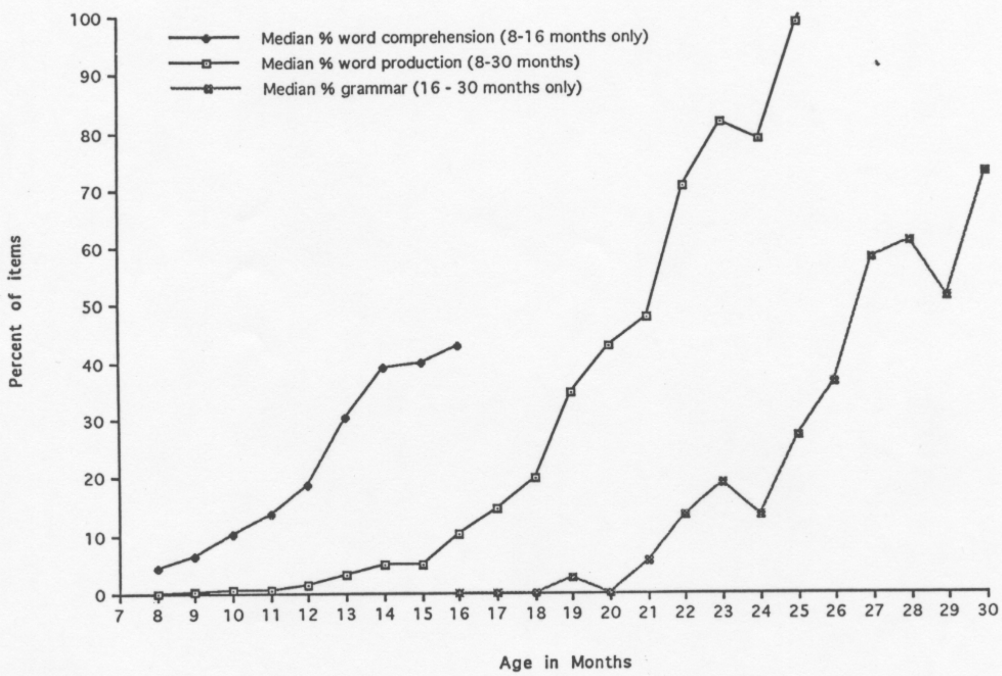
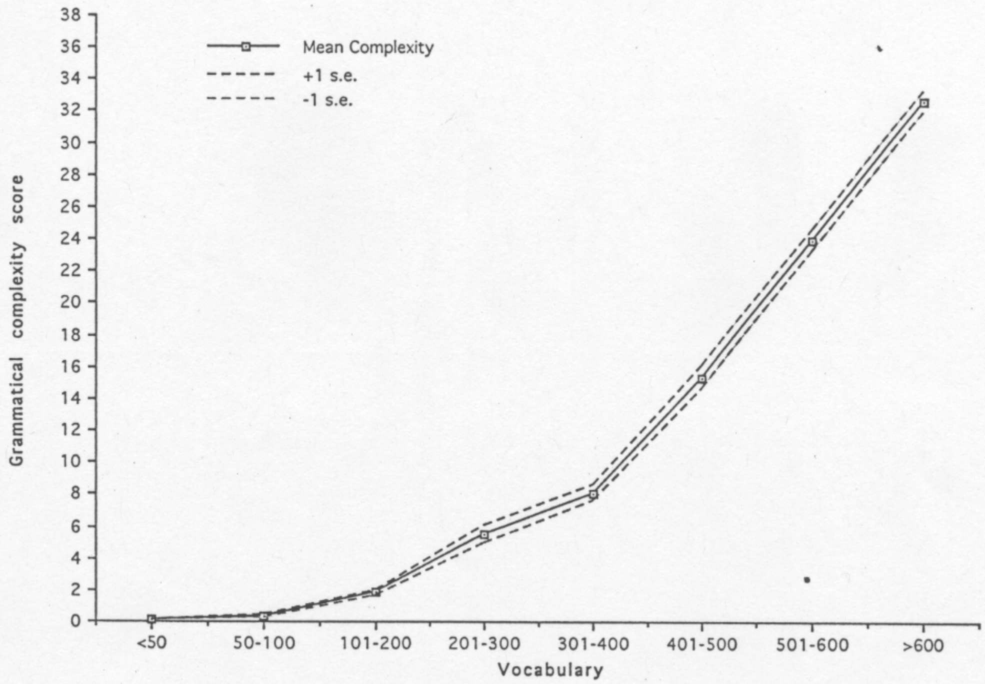


Figure 3



Median growth scores for word comprehension, production and grammar expressed as a percent of available items

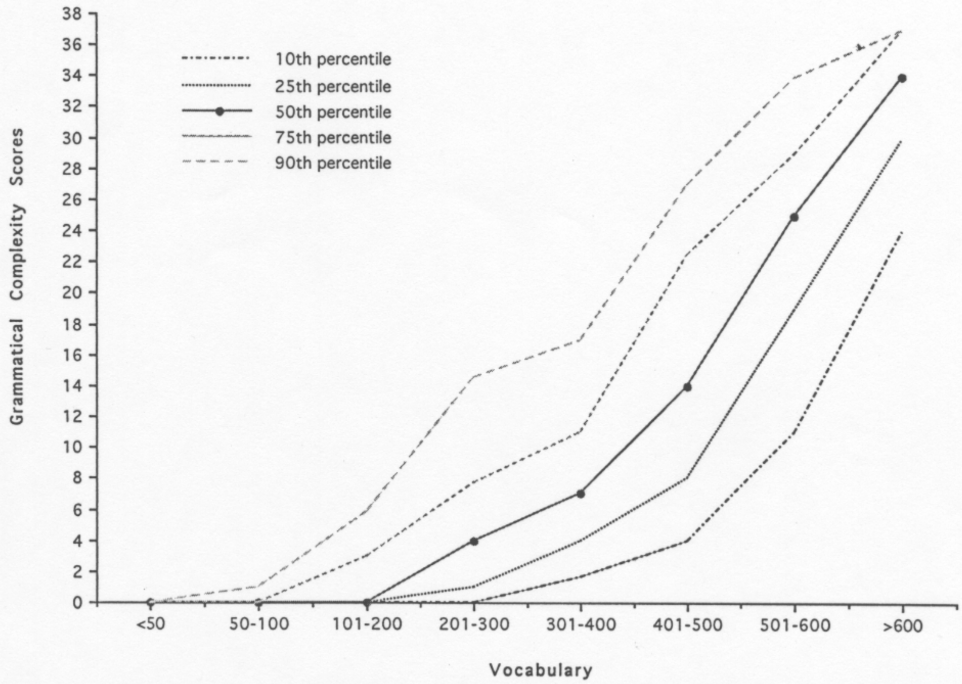
Figure 4



Mean and standard errors for grammatical complexity in children at different vocabulary levels.

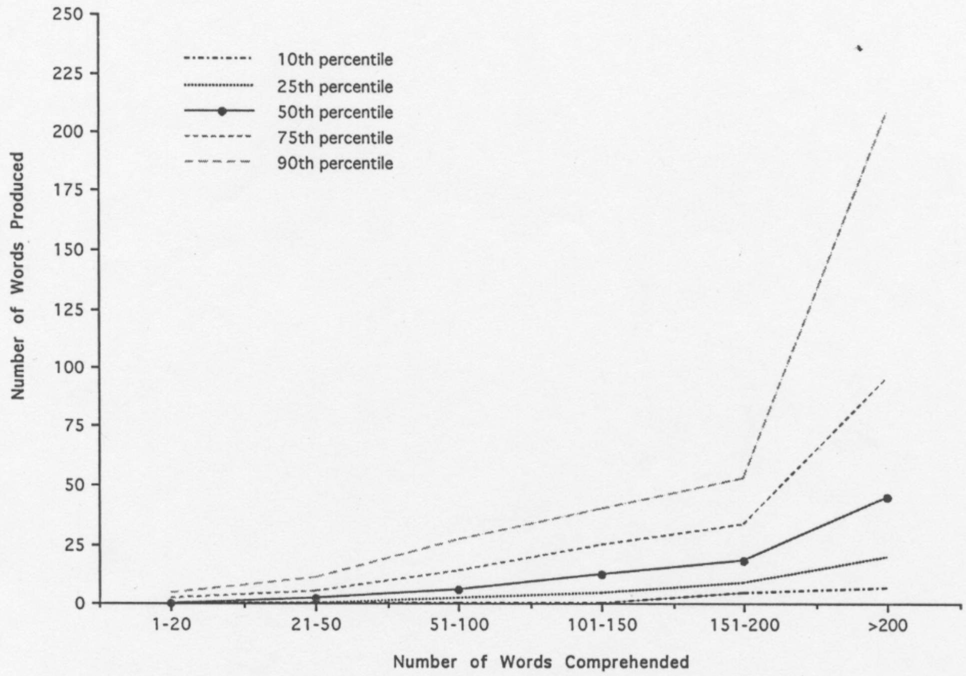
From Bates and Goodman (1997).

Figure 5



Relationship between grammar and vocabulary size: variation within each vocabulary level

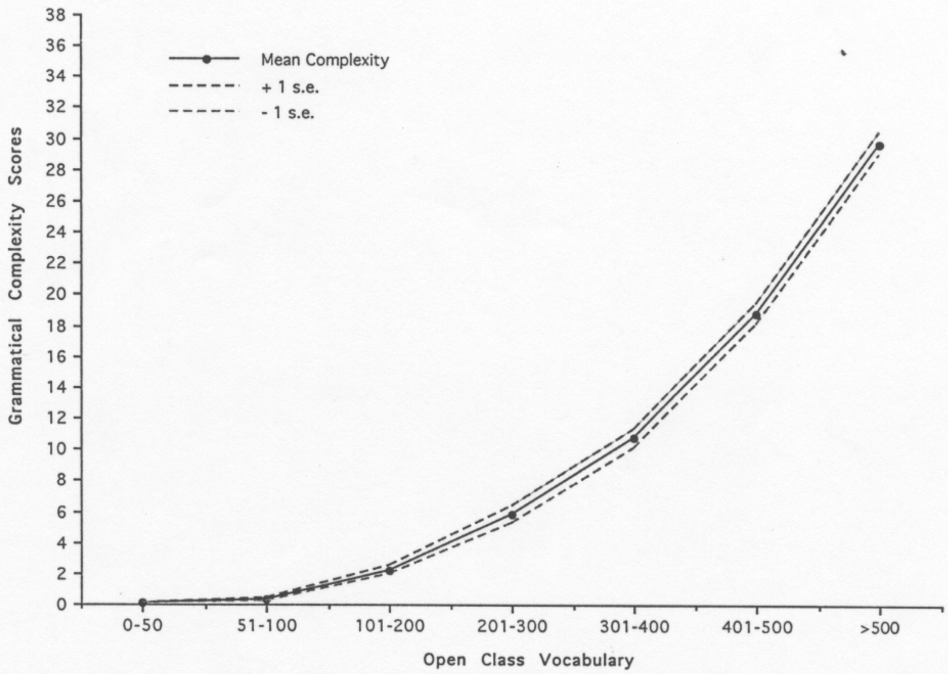
Figure 6a



Variability in Word Production as a
Function of Comprehension Vocabulary Size.

From Fenson et al. (1994).

Figure 6b



Grammatical complexity as a function of open class vocabulary only

Figure 7

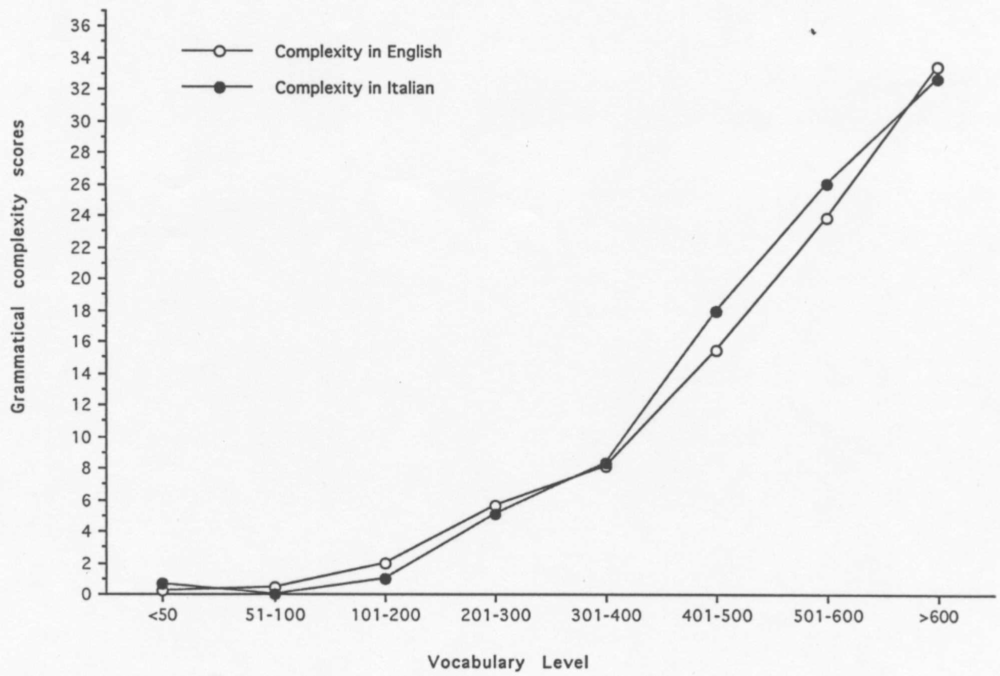
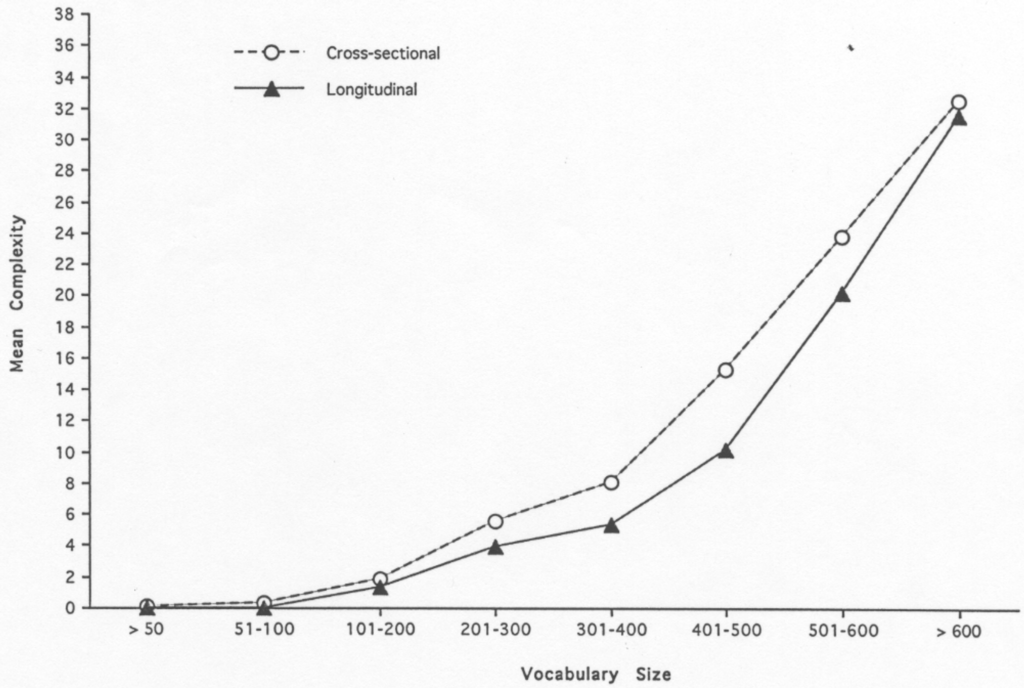


Figure 8: Grammatical complexity as a function of vocabulary size.

From Caselli, Casadio, and Bates (1998).



Grammatical complexity as a function of vocabulary level
for the cross-sectional vs. longitudinal samples

Figure 9

Reported production of 16 Irregular verbs as a function of verb vocabulary size

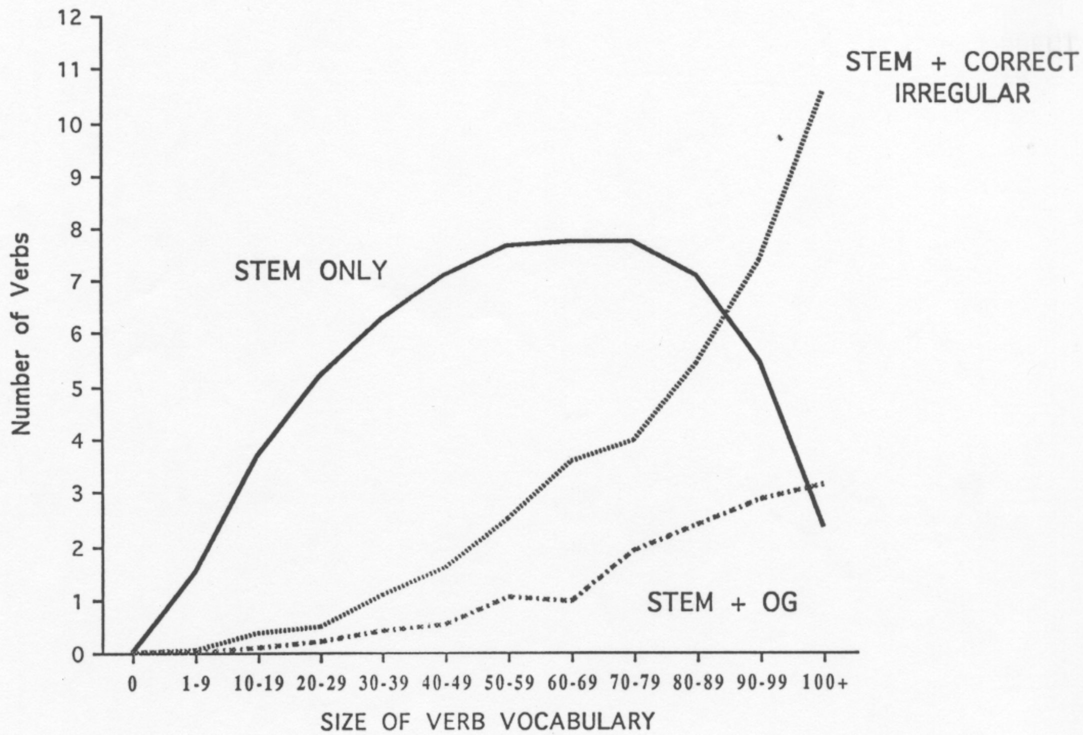
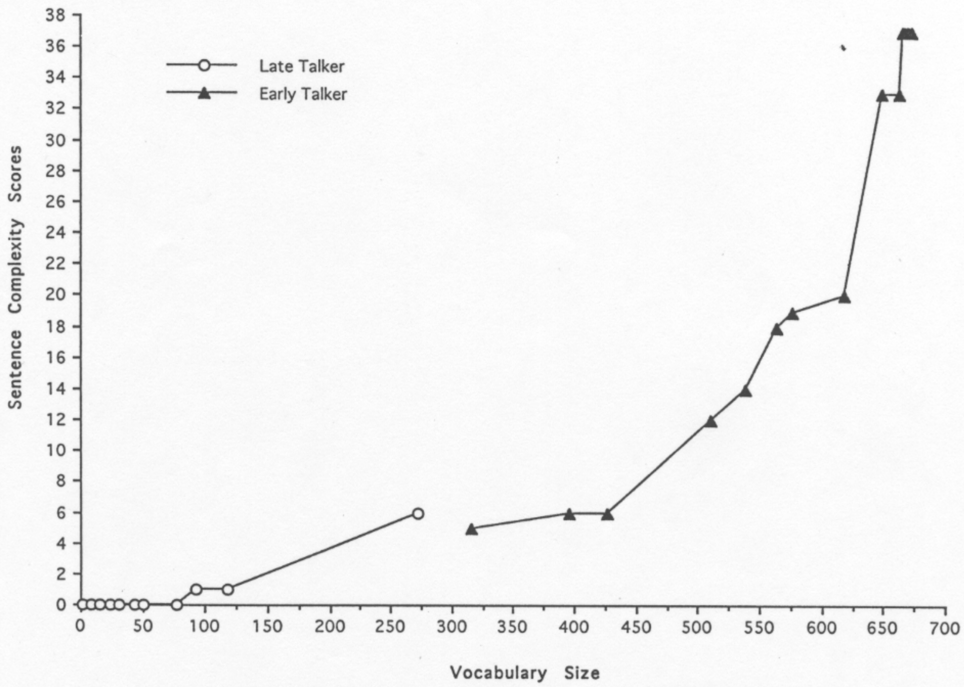


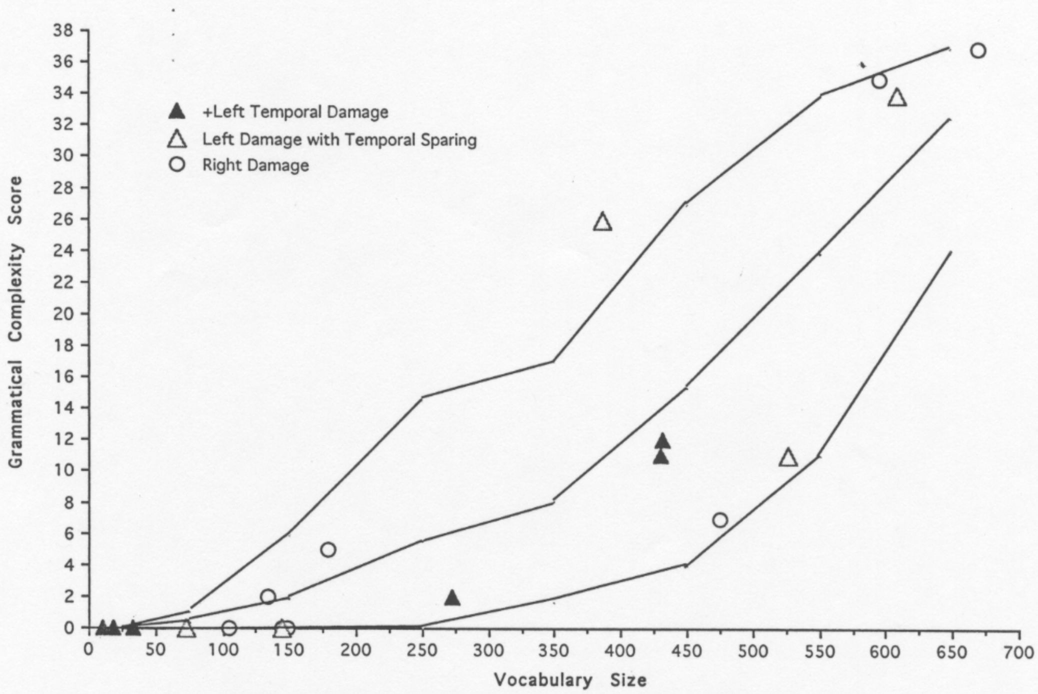
Figure 10



Relationship between Grammatical Complexity and Vocabulary Size for One Late Talker and One Early Talker

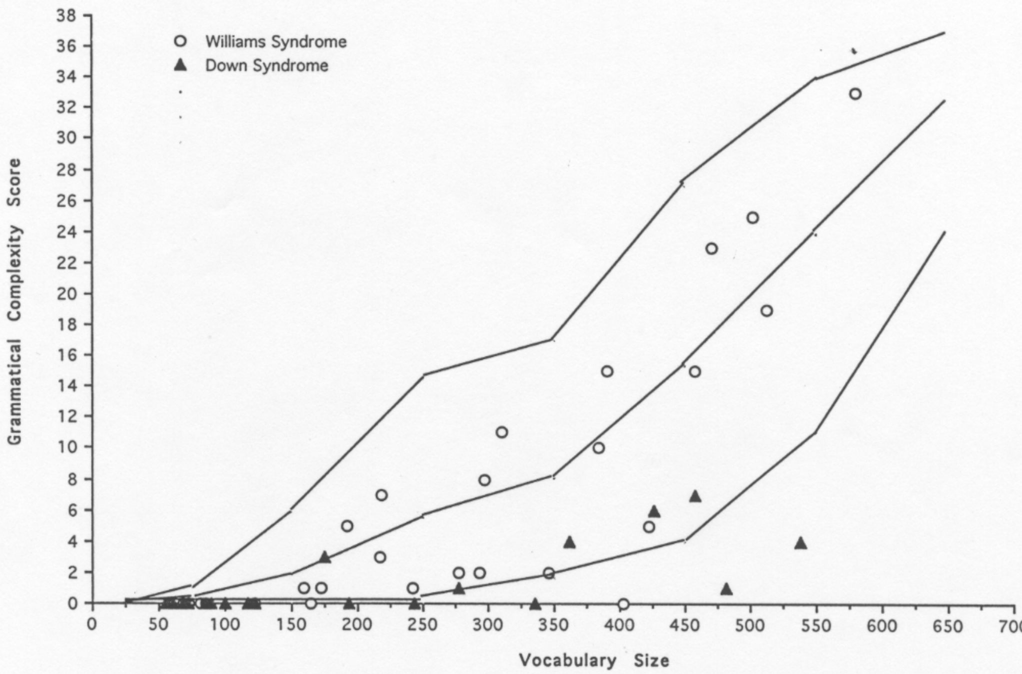
From Bates and Goodman (1997).

Figure 11



Grammar as a Function of Vocabulary Size
in Children with Focal Brain Injury
(lines = 10th, 50th & 90th percentile for normals)

Figure 12



Grammar as a function of vocabulary size
in children with Williams vs. Down Syndrome
(lines = 10th, 50th and 90th percentiles for normals)

Figure 13