EVOLUTIONARY DEVELOPMENTAL LINGUISTICS

Naturalization of the Faculty of Language

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Abstract

Since language is a biological trait, it is necessary to investigate its evolution, development, and functions, along with the mechanisms that have been set aside, and are now recruited, for its acquisition and use. It is argued here that progress toward each of these goals can be facilitated by new programs of research, carried out within a new theoretical framework---one that could be called "evolutionary developmental linguistics" (EDL)---respecting current developments in biology, anthropology, psychology, and cognitive neuroscience. EDL is concerned with the evolution of developmental properties, processes, and stages (evo → devo) that independently, or in concert with other environmental changes, facilitated the emergence of language in the species (devo → evo). I describe recent work carried out within this framework, and suggest future lines of research. The faculty of language stands to benefit from a synthesis of evolution and development, as does the field of linguistics.

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Language is a species-specific trait that evolved in humans uniquely, and develops in the young universally. A strong biological endowment was suspected fifty years ago when it was noted that infants acquire linguistic material at a fairly brisk pace, considering the seeming inadequacy of ambient models and the rarity of teaching or corrective feedback (Chomsky 1959, 1980; also see Anderson & Lightfoot 2002; Crain & Pietroski 2001). Later, it was observed that infants appear to invent aspects of linguistic structure---as when pidgins are transformed into creoles (Bickerton 1984)---and that deaf children streamline or embellish sign languages that have been awkwardly modeled by their non-natively signing parents (Goldwin-Meadow & Mylander 1998; Newport 1981). Recently, the lexical and grammatical inventiveness of our species was dramatized in two socially disparate populations of linguistically deprived deaf individuals (Sandler et al. 2005; Senghas & Coppola 2001; Senghas et al. 2004). If only a portion of the language known by these individuals originated outside of their heads, then the rest, according to the operative assumption, must have come from the inside.

One consequence of the strong role played by *internal* factors is a course of development that appears relatively uneventful to outside observers, who may think that language, given its size and complexity, should require more effort than is actually witnessed. In some societies, to be sure, parents direct a great deal of talk to their infants, and speak more slowly, or with exaggerated prosody; and they usually supply the names of particularly salient objects, actions, and concepts. These practices, or the disposition to engage in them, may or may not be associated with unusual levels of language learning (Hart & Risley 1995; Nelson et al. 1973), and may even be less helpful, in some respects, than merely modeling speech (Akhtar 2005). But they

cannot be essential, since infant-directed speech is rare in some societies (Ochs 1982), and it is unusual, in any culture, for caregivers to do much that is specifically tutorial---they do not, and probably cannot, teach grammar, nor do parents instruct their progeny in the principles of pragmatics or verbal performance.[1] "This disparity between knowledge and experience is perhaps the most striking fact about human language," wrote Chomsky forty years ago. "To account for it is the central problem of linguistic theory." (Chomsky, 1967, p. 438)

The disparity has practical as well as theoretical consequences. When we chart the infant's development from birth to first words, there are remarkably few things that are known to *belong* in the record. To be sure, words are frequently preceded by various "events" such as babbling and pointing. But observational studies have been carried out for some decades now, and there is still a great deal of uncertainty about which of the behaviors that precede language also facilitate or enable it---if any. This may be why there are few formal theories of language development, and few components in the accounts that do exist. A model of language development can look no more complicated than the one displayed in Figure 1.

Insert Figure 1 here

The sequence depicted in the Figure begins with evolution, which provides the genes that, in collaboration with maturation and experience, build the neural mechanisms that acquire utterance material and infer grammatical rules (Locke 1992, 1994a). In this sense, language develops like other processes that are due conjointly to selection and instruction (cf. Jablonka & Lamb 1998).

If the principle components of language development are already known, as Figure 1 implies, some linguists may be tempted to spend their time on other problems. But when we ask *how* these components do their work, serious problems arise immediately. If the process is approached from the genetic side of the equation, we discover that genes are not, by themselves, as powerful as has been assumed. West-Eberhard (2003) has pointed out that contrary to the impression given by genetic-control metaphors for development, "the bare genes in isolation are among the most impotent and useless materials imaginable." (p. 93) Gottlieb (2007) has pointed

out that genes "require intracellular signals, some of which originate from outside the cell and, indeed outside the organism." (also see Plomin & Bergeman 1991; Rutter 2007).

If we shift our attention to the environment---the source of the material that is acquired---we encounter other problems. One is that the *effective* environment is a function of the infant's perceptual orientation, which is affected by genes (as well as experience: Gottlieb 1991a,b). A second problem is that infants create their own environments, also under the influence of genes. This process, which has been called "niche picking" (Scarr & McCartney 1982), seems analogous to the evolutionary process of "niche construction" (Olding-Smee et al. 2003), according to which an organism's behavior alters the external forces to which it must adapt (see Bateson 1988; Gottlieb 2002; and discussion in Dawkins 2004). In this sense, "the environment" is neither a unitary nor a strictly external or extra-genetic force in development, and this adds to the difficulty of evaluating gene-environment interactions.

My point about gene-environment interactions is not that they are insoluble. It is that issues of this nature and complexity cannot be investigated without an appropriate theoretical framework. But the need to grapple with complex gene-environment interactions is not the only reason for adopting a more suitable approach. There are other, more local problems, including the degree of linguistic specificity and exclusivity of the mechanisms that are recruited by language (Christiansen & Chater in press)---whether attentional and perceptual or lexical and computational---and the nature of the neural and cognitive processes that coordinate actions of theoretically different systems. Solutions to these problems will require the collaboration of investigators in various disciplines, including linguistics.

Evolutionary developmental biology

Recently, biologists have begun to develop a synthesis of evolutionary biology and developmental biology, sensing the opportunity to learn more about each by studying the two together (Gilbert 2003; Hall 1999, 2001, 2002, 2004; Minugh-Purvis & McNamara 2002; Wagner 2000; Wagner et al. 2000; West-Eberhard 2003). In 1999, The Society of Integrative and Comparative Biology inaugurated a new journal, *Evolution & Development*, and established a division of Evolutionary

Developmental Biology the following year (Hall 2000; Wagner 2000). This endeavor has all the earmarks of a new discipline---*evolutionary developmental biology* (EDB)---the goals of which, among others, are to synthesize proximate and ultimate explanations in biology; to explain how modifications of development and developmental processes produce novel features; to increase present understandings of the adaptive plasticity of development in life-history evolution, and the manner in which ecology impacts on development to modulate evolutionary change (Hall 2000; Laubichler & Maienschein 2007; Wagner et al. 2000).

Evolution and development in psychology

Evolution has also come to play an important role in psychology, especially in research on cognition and behavior, including their development. It began to do so about twenty years ago, when psychologists framed the basic assumptions and operating principles of *evolutionary psychology* (EP; Cosmides & Tooby 1987; Crawford & Krebs 1998; Pinker 1997; Tooby & Cosmides 1990), with some priming from and, later, collaboration with researchers in anthropology (Barkow et al. 1992; Chagnon & Irons 1979; Irons 1998; Irons & Cronk 2000; Symons 1990). EP is concerned with human behaviors that are supported by adaptive information-processing mechanisms, ones that enabled (or would have enabled) our ancestors to solve problems persistently encountered during the long and relatively stable Pleistocine period (Kanazawa 2004).[2] "The evolutionary process designed the neural machinery that generates intelligent behavior," wrote Cosmides and Tooby (2002) in a statement of the rationale for EP, "and important insights into how this machinery works can be gained by understanding how evolution constructs organisms. (p. 145) The larger goal, as Franks (2005) sees it, has been to "naturalize" psychology by putting it in touch with the natural sciences.[3] If the review by Buss and Reeve (2003) is any indication, EP has achieved an impressive empirical record since its inception in the late 1980s.

In developmental psychology, more recently, the cornerstones of a new sub-division, *evolutionary developmental psychology* (EDP), have been laid. The goal of EDP, wrote Geary and Bjorklund (2000), "is the study of the genetic and ecological mechanisms that govern the development of social and cognitive competencies common to all human beings and the epigenetic (gene-environment interactions) that adapt these competencies to local conditions." (P. 57) In a more

extensive treatment of EDP, Bjorklund and Pellegrini (2002) treat EDP as a metatheory for developmental psychology, bringing into a unifying evolutionary framework such diverse problems as sensory development, spatial cognition, play, and theory of mind (also see Burgess & MacDonald 2005). At present, EDP is intent on the interpretation of behavioral and cognitive development in light of evolution. How actively this new field will formulate and test its own hypotheses remains to be seen.

At this writing, there is at least one additional venture that explicitly values the contributions of evolution and development to human cognition. It is called *evolutionary cognitive neuroscience* (ECN). ECN is dedicated to interactions of genes and environment, as they affect brain, mind, and behavior, with evolution serving as the unifying factor. The book announcing this new initiative deals with the development and evolution of the brain, kin selection, spatial cognition, and self-awareness, among other topics (Platek et al. 2007; also Krill et al. 2007). Not surprisingly, it also contains a chapter on language (Corballis 2007).[4]

Like the other cognitive sciences, it is time for linguistics to pursue the faculty of language in an evolutionary and developmental framework, especially one that values *interactions between evolution and development*. If it does, the new initiatives will have a solid empirical foundation from the start, with potentially enormous theoretical benefits. Recently, Finlay (2007), a psychobiologist, identified language as one of a few areas that would particularly benefit from research within an evo-devo framework. A new branch of linguistics, "Evolutionary Developmental Linguistics" (EDL), would be able to import findings from research in the other fields of cognitive and developmental neuroscience, and export theory and data to those fields. The result is almost certain to be a better understanding of language itself.

NATURALIZATION OF LANGUAGE AND LINGUISTICS

Research has been moving vaguely in the direction of EDL for at least forty years, possibly stimulated by Lenneberg (1967) and Chomsky's agenda-setting pronouncement on the disparity between knowledge and experience of language. It seemed to begin with psychological

experiments, the first of these relating to speech perception in human infants (Eimas et al. 1971) and other mammals, including nonhuman primates (Kuhl & Padden 1983; Morse & Snowdon 1975). One model of perception, inspired by research in behavioral embryology by Gilbert Gottlieb, envisaged the possibility of interactions between pre-adapted perceptual categories and environmental experience (Aslin & Pisoni 1980). Other work investigated prenatal learning of maternal vocalization (DeCasper & Fifer 1980), and the loss and realignment of pre-experiential perceptual boundaries for speech sounds toward the end of the first year of life (Werker & Tees 1983; Werker et al. 1981). In parallel, other investigators were looking at patterns of vocal production in relation to reduced or varied ambient experience (Boysson-Bardies et al. 1989, 1992; Oller & Eilers 1988), or examining the emergence of phonetic or phonological properties that were universal or rare (Locke 1983, 2000; Locke & Pearson 1992; Ohala 1980).

Following on from the new work on development, there was also a renewal of the historical interest in linguistic evolution. As the 1990s began, Pinker and Bloom were pointing to "a wealth of respectable new scientific information relevant to the evolution of language" (1990, p. 727). Since then, the flow of books on the evolution of language has averaged more than one per year, and journal articles and book chapters have increased ten-fold (Christiansen & Kirby 2003). To some, it was becoming evident that the new developmental and evolutionary data were becoming, or would eventually become, difficult to integrate and interpret.

In other quarters, two insights were emerging about the role of evolution in development. The first was that evolution is the source of some important *developmental properties* of our species, e.g., neoteny and related cognitive factors, that may have played a role in the evolution and development of language (Bjorklund 1997; Locke 1993a; Newport 1990). The second insight is that evolution is responsible for *developmental stages* inasmuch as environmental changes, at various points in evolutionary history, inserted new intervals into the growth cycle of our species (Bogin 1988, 1999b) and remodeled other stages (Locke & Bogin 2006). These new and altered stages of human life history produced new proto-linguistic behaviors that enhanced reproductive advantage, increasing the distribution of linguistically supportive genes in the species.

Resistance

Through the years, Chomsky and his followers have repeatedly declared that language is a biological trait, and that linguistics should therefore be considered a branch of biology (Lorenzo & Longa 2003). Anyone reading these statements might suppose, Chomsky's influence being what it is, that over the same period there has been a steady flow of linguists into the biology of language, and that there might now be a separate field of biolinguistics. Since biology is achieving a "vibrant synergy and synthesis" of evolution and development (Hall 2000), and psychology is enjoying much the same experience, one might suppose linguists have also been drawn to the relationship of these central issues in the construction of language.

The reality is very different. There is no "field" of biolinguistics, even if the term has been used on occasion (Fitch 2007; Locke 1993a,b, 1994b, 2001; Jenkins 2000), and most of those who study language development are not linguists.[5] The principle issues in the *launching* of language---from joint attention, imitation, and attachment to vocal-motor development, speech perception, and the development of social cognition---have been pursued mainly by psychologists. Linguists have been heavily involved in "child language," of course, and this research has helpfully documented the emergence of language in the young. Some recent research has even attempted to locate a genetic basis for the timing of important developmental linguistic events (cf. Wexler 2002). But linguists usually defer to other disciplines when it comes to the investigation of underlying developmental mechanisms and processes that account for this emergence, including the growth of the brain; the role of emotional factors and social relationships; and the nature of gene-environment interactions. By the time that linguists do tune in---usually after infants begin to speak---many of the important developments have already occurred.[6]

When it comes to evolution, the "missing linguist" phenomenon has become so obvious as to require comment (Bickerton 2003; Newmeyer 2003), and Newmeyer has suggested reasons. First, he says, one needs to have a good idea of what a trait is if one is to study its evolution, and we do not know the properties of universal grammar (UG).[7] Second, Chomsky's skepticism about the applicability of selection-based claims discouraged linguists from looking for a Darwinian account of UG or any other part of language. Third, our homologous ape cousins,

according to Newmeyer, can muster no more than "a few calls and grunts," providing grammarians with an inauspicious point of departure. Fourth, linguists who fell under "uniformitarian" thinking believe that there are no "primitive" languages anywhere in the world, and thus are ill-equipped to study anything but the faculty of language in full flower (child language specialists may be surprised to learn this).[8]

Clearly, it is time to move on, as Newmeyer and Bickerton are personally ready to do. My purpose here is to encourage linguists to exploit the possibilities of EDL, lest the faculty of language be defined by individuals with less knowledge of language, and less of a stake in how linguistic issues are ultimately resolved. I will illustrate some ways that evo → devo and devo → evo processes may have enhanced the capacity for language, revisiting several proposals that have recently been presented in detail elsewhere (see details and supporting evidence in Locke 2006a,b; Locke & Bogin 2006). I will also examine the potential of EDL to change the field of linguistics by encouraging the inclusion of currently peripheral areas---pragmatics and performance---and by generating new research questions. Before I begin, however, it is appropriate to bring into the open what may be an obvious fact: much of the evolution and development of language is not, by the nature of these constructive processes, linguistic. Indeed, the conventionally recognized components of language do not and cannot appear until a late stage in either process, and much of what is said here will relate to what may have been early stages. As I am most interested in selection-based accounts of language, my discussion will deal most explicitly with processes that may have preceded the appearance of grammatical systems.

The role of evolution in development

As indicated, stages of development are, themselves, the products of evolution. The importance of this fact is linked to a second fact: new traits evolve, during development, and *can only do so then*. Eighty-five years ago, Walter Garstang pointed out that it was "absurd" to suppose that a new trait could evolve in mature members of the species (Garstang 1922). In the interim, his judgment has been repeatedly confirmed (de Beer 1958; Gould 1977; Hall 2002; Northcutt 1990; West-Eberhard 2003). Although few linguists (and other scholars) have taken note, no proposal on the adaptive evolution of language can be complete without specification of the

environmental changes that produced the new traits in development, and the reasons why the new traits would have conferred reproductive advantage. I will characterize the supporting evidence for this (devo → evo) process shortly, but will begin here by discussing the evolution of developmental stages themselves: evo → devo.

To be prepared for a socially complex adulthood, and ours is as complex as they get (Dunbar 2007; Whiten & Byrne 1997), there must be appropriately structured intervals for development and learning. Humans have four such stages---two more than the other primates. We also have two stages that were remodeled (Bogin 1999a). A proposal that emerges from EDL is that all four of these new and remodeled stages were needed for language to evolve, and that all four are needed for the young to acquire language and to become fully proficient in its use (Locke & Bogin 2006).

In an important paper, Studdert-Kennedy (1991) argued that certain sequences that occur in the development of language, e.g., syllables and formulaic phrases before phones and features, and words before simple sentences, would also have occurred in evolution, a generalization with which other evolutionary theorists agree (e.g., Bickerton 1995, 2000; Wray 1998). Studdert-Kennedy went on to comment that such parallels were obligatory, not because the ontogenetic course of language is coded in the genes, as Haeckel had erroneously claimed at the close of the 19th century, but because structure differentiates with growth. Studdert-Kennedy's observation offers added theoretical value to devo → evo by justifying the cautious use of ontogeny to reconstruct the evolutionary role of developmental stages. Thanks to a great deal of research on human life history, the stages through which the young pass on their way to adulthood are demarcated by nonarbitrary criteria relating to physical growth, cognitive development, social independence, sexual maturity, and related variables (Bogin 1999b). Before continuing, it is essential that we take a brief look at these stages.

Infancy. Infancy begins at birth and ends at about 30 to 36 months when, in traditional societies, the child is weaned from the breast. This stage is characterized by rapid physical growth---the most rapid of any of the developmental stages---as well as provision of nourishment by maternal lactation and eruption of deciduous dentition. Human infants are more helpless

than ape and monkey infants, a "deficiency" that requires a long period of continuous care. The associated interactions facilitate acquisition of socially complex behaviors, including language. It is thought that the initial change that produced greater helplessness was bipedal locomotion, which eventually realigned the spine and narrowed the pelvis. This produced problems at birth for the mother and her large-headed fetus. There being a range of variation among infants, some had smaller heads at the time of birth, and these infants---and their mothers---were more likely to survive the delivery. Over time, differential rates of survival caused a shift in skull and brain development from the prenatal to the postnatal period. Later, I will discuss ways that this shift may have produced more complex and controlled forms of vocal communication.

Childhood. Childhood is a uniquely human stage that is thought to have entered the *Homo* line about two million years ago (Bogin 2001, 2003). Since chimpanzees wean at four to five years, it is assumed that earlier weaning liberated about two years from infancy. This is what created childhood (Bogin 1990). It has been suggested that the extension of childhood to its present length---which extends from about three to nearly seven years---was due, at least in part, to the increasing functionality of communicative behaviors in this stage (Locke & Bogin 2006). Nonlinguistic characteristics of childhood include slow and steady growth and relatively small body size, a large and rapidly expanding brain, a higher resting metabolic rate than other mammalian infants, immature dentition, dependence on others for care and feeding, and a number of motoric and cognitive advances (Bogin 1990). As childhood draws to a close, there are two important changes: a brief increase in the rate of brain development, which ends a period of steady deceleration in rate, and an improvement in the ability to eat, reflecting the presence of new teeth and increases in the size and strength of the lower jaw.

Juvenility. Juvenility begins at seven years, with the onset of adrenarche---a change in the adrenal system in which increases in androgen produce some secondary sexual characteristics in advance of puberty---and accompanying cognitive and social advances, and ends at ten and twelve years in females and males, respectively. Individuals in this stage are sexually immature but much more independent of older individuals than are children. Coming after a remodeled infancy and new childhood, the juvenile stage of our evolutionary ancestors could hardly have remained as it was. In various species of mammals, juvenility provides additional time for the

brain growth and learning required for reproductive success (Janson & van Schaik 1993; Joffe 1997). In complex human societies, it takes the totality of juvenility and adolescence for the social and linguistic skills that are needed in sexual maturity to develop. Among the tiny bands of hunter-gatherers who occupied the open savannahs of sub-Saharan Africa, these skills would have included the persuasive and attractive use of speech, and the ability to fluently manipulate elaborate and socially appropriate utterances. Modification of juvenility would naturally increase phenotypic variability and offer new bases for selection at a time when greater independence and sexual maturity were rapidly approaching.[9]

Adolescence. Adolescence is the second stage that is uniquely human, the other primates proceeding directly from juvenility to adulthood (Bogin 1999b). This stage begins at the end of juvenility and extends to nineteen years, when adulthood commences. In modern humans, adolescence is announced by puberty and a simultaneous surge in skeletal growth, strengthening of friendships, and development of new relationships. Recent imaging research is now indicating that adolescence, to a surprising degree, is a time of renewed brain development. The volume of cerebral gray matter sharply decreases from childhood to adolescence, evidently due to dendritic pruning, and there are large increases in white matter, caused by myelination, increases in axonal size, and glial proliferation (De Bellis et al. 2001; Giedd 2005; Giedd et al. 2001; Shaw et al. 2006). This pattern of exuberant growth and pruning is relevant to arguments that adolescence conferred reproductive advantages on our ancestors, partly by giving the young additional opportunities to acquire social and sexual skills before reproducing (Bogin 1999a, 1999b). From a linguistic standpoint, it fits with this conception that adolescence provides opportunities to learn the pragmatic and other skills needed to converse and narrate (Dorval & Eckerman 1984; Nippold 1998). It also offers opportunities to learn slang, idioms, and other formulaic patterns, which collectively contribute to group solidarity and enhance the ability to perform, partly by increasing the fluency and rate of articulation (Kuiper 1996). Other performance skills developing in adolescence include gossiping, joking, arguing, negotiating, and persuading. All these skills stand to impress peers and facilitate the achievement and maintenance of social relationships.

Speech, sex, and status

These adolescent trends call our attention to some special relationships between speech and two resources that are valued by primates generally---sex (reproductive success) and status. In a range of human societies anthropologists have noted unusual linguistic knowledge and rhetorical skill in individuals, invariably men, who have risen to positions of authority and power (Burling 1986; Locke 2001; Locke & Bogin 2006). Various tribes have a "Big man," a skilled orator who is also, by no coincidence, the group's leader. These "rhetoric thumpers," as they have also been called, represent the group in all dealings with outsiders, and in rituals and ceremonies. According to Reay (1959), who studied the Kuma people of New Guinea, the rhetoric thumper is

> fluent in idiom and eloquent in delivery. He struts vigorously backwards and forwards about eight paces as he orates. He swings his hatchet as he walks, and often holds a carved spear upright in his other hand. He speaks in clearly measured periods: the shorter statements extended by repeating *a-a-a-a-a*, the longer ones spoken more rapidly, so that each corresponds in time to a set of paces in one direction. What is said as he goes is often balanced exactly by what is said as he comes back; the subject perhaps is varied in twin sentences of identical construction. (p. 118)

As to how the thumpers achieve their rhetorical force, Reay commented specifically on "subtle uses of alliteration, rhyme, and consonance, and the development of a kind of sprung rhythm after an initially regular metrical form." (p. 118)

The Kuma people may seem unique, but a thorough reading of the anthropological research indicates that many groups have had an individual who acted as the leader, and this person was invariably a man who was inclined to, and gifted in his ability to, speak monologically in a way that commanded favorable attention (see reviews in Locke 2001; Locke & Bogin 2006). Men also engage in verbal duels---one-on-one competitions in which the weapons are usually ritualized insults, exchanged with humorous undertones. These social displays require an audience, and since the audience is usually mixed, the reward for winning a duel is enhanced dominance and new opportunities for sex. Highly stylized duels have been reported in diverse places and

cultures all over the world. Collectively the speech of leaders and duelists is distinguished by its prosody, fluency, rhythm, rate, reaction time, tone of voice, humor, and unusual words and expressions (Locke & Bogin 2006).

Since women are capable of dueling, one may wonder why I have chosen to concentrate on the public displays of men. The reason is that they help us bridge a wide theoretical chasm between our own species and the apes. Primate research continues to document the role of male vocal displays in mate selection (Delgado 2006; Fischer et al. 2004; Palombit et al. 1999). This is consistent with a general tendency, across the animal kingdom, for males to compete with each other for mates (Andersson 1994; Hamilton, 1985; Harvey & Arnold 1982; Mayr 1972), and to do so by *displaying* (Bastock 1967), that is, by overtly behaving in ways that provide fitness information to females. This disposition is twinned with a tendency for females to *select,* that is, to choose mates based on this information, suggesting that female perceptual response may have influenced the form of male displays (Endler & Basolo 1998; Fisher 1930; Guilford & Dawkins 1991). As we will see, there is evidence in our own species for male vocal displays where, in some cases, the vocal variable that is manipulated corresponds to the perceptual preferences of females.

Theoretical benefits of evo → devo to language development

In research on language development, there is a tendency to focus on infancy and childhood, probably because it is during these stages that knowledge of words and grammatical rules is acquired. This accords well with implicit views of language as an object (Bickerton 2006). But knowledge of language enables one to speak, thus to act in social situations, and to express oneself in social groups. By adopting human life history as our theoretical framework, we are encouraged to ask about the contribution of each developmental stage, from infancy and childhood through juvenility and adolescence, and it is during these later stages that this second (social) view of language becomes more salient. It is for these reasons that developing individuals who speak in accepted ways should experience far more social success than those who do not, and there is no shortage of evidence that this is so. However, the basis of social acceptance (and rejection) at sexual maturity is not linguistic knowledge and structure so much as vocal and verbal performance (Locke & Bogin 2006). Clearly, the relevant *speaking skills*---the perceptible

and, from a causal standpoint, proximate behaviors---presuppose prior accomplishment in all areas of language, however inconspicuous these accomplishments might be initially. As Hale (1992) has written, "Some forms of verbal art---verse, song, or chant---depend crucially on morphological and phonological, even syntactic, properties of the language in which it is formed. In such cases the art could not exist without the language, quite literally." (p. 35)

The role of development in evolution

There is more to say about these issues, but we also need to ask about the role of development in evolution. Since Chomsky began to address the subject, linguists have assumed that *something* a very long time ago paved the way for language development in modernity, but it may seem strange to suggest that this thing---whatever it was---could have been launched by immature beings. Even within biology it was thought, by no less than Darwin himself, that the individuals to whom his theory of natural selection applied were fully-formed adults. But right from the start some biologists asked how evolution could occur without the involvement of the young. Just twelve years after *The Origin of Species*, St. George Mivart, a critic of Darwin, discussed "direct embryonic modifications," and suggested that new species emerged from "affections of their generative system" (1871, p. 267).

A half-century later, Walter Garstang (1922) wrote, "The phyletic succession of adults is the product of successive ontogenies. Ontogeny does not recapitulate Phylogeny [as Haeckel had proposed]: it creates it." (p. 98) In a later paper, Garstang (1928) wrote that new characters "may arise at any stage in the ontogenetic sequence." (p. 62) But the force of changes in *early* stages is likely to be unusually significant, for "a character which appears early in ontogeny," as Gavin de Beer (1959) was later to observe, "has time to produce more important changes." (p. 97)

It is now accepted that evolution is a two-step process (West-Eberhard 2003; also Gottlieb 2002; Gould 1977). In the first step, a plastic phenotype responds to environmental variation---in development---producing novel forms that vary genetically. In the second step, selection acts on the variants. After genetic variations are produced or forced to the surface, selection screens

these developmental products of these genotypes and determines which will persist and multiply across generations. A selection-based account of language cannot be complete unless it identifies the causes of phenotypic plasticity, the linguistically favorable genetic variations that arise in ontogeny, and the processes of selection that reinforced and expanded those variations, and it is highly probable that infancy played a major role in all these areas.

With much of linguistics devoted to syntax, a late-developing ability, and most evolutionary speculation occurring from an "adultocentric" perspective, it is not surprising that scholars would overlook the role of infants, who typically display little knowledg of syntax until the end of that stage. What could infants---individuals whose name derives from their lack of linguistic ability (*in fans*, literally "not speaking")---have possibly contributed to the abstract and complex codes of human language?

It helps to begin by recognizing the kinds of changes that might have been required, and that infants could have contributed. The other primates, as Newmeyer (2003) implied, do not have elaborate vocal signaling systems. They show little aptitude for vocal learning (Owren et al. 1992, 1993), and may have little (cortical) ability to control their vocal tract activity. The other primates also give little evidence that they use their voices intentionally to inform others (Owren & Rendall 2001). But at some point our evolutionary ancestors obviously "went vocal." How could this have happened?

The logical starting point is perceptual. The differentiation of communicative behaviors begins with a receptive system of appropriate sensitivity, and here the primate data are rather more encouraging. In baboons, (male) calls provide cues to age, competitive ability, and stamina as well as rank (Fischer et al. 2004; Kitchen et al. 2004; Seyfarth & Cheney 2003). In rhesus monkeys, cues to the body size of callers lie in harmonics that resemble the formants of linguistic vowels---and it is now evident that monkeys use these patterns to infer the size of conspecifics (Ghanazafar et al. 2007; Pfefferle & Fischer 2006). These findings are clearly relevant to an evolutionary linguistic account, for they suggest that apes are aware of a range of subtle vocal variations, some not unlike those that are systematically manipulated in human speech. Thus

one assumes that similar sensitivities existed in our ancestors, readily exploitable by competitive signalers.

Research now indicates that human listeners---even those who know nothing of primates---are also able to discriminate individual monkeys from their coos and screams, naturally and without training, much as they discriminate between members of our own species from isolated vowel sounds (Fitch 2006; Owren & Rendall 2003). Humans are also able to categorize primate calls according to their affective characteristics (Leinonen et al. 1991). In laboratory experiments, human infants are able to discriminate languages that belong to different rhythm classes, e.g., Polish and Japanese, but do not differentiate languages that share such classes, e.g., English and Dutch (Nazzi et al. 1998), and much the same is true of cotton-top tamarins exposed to similar materials (Tincoff et al. 1998). These results suggest that primate cortex may be activated by speech and conspecific vocalizations alike (though see Trout 2003), that auditory mechanisms may be used to analyze prosody, and by implication, that some stages of linguistic analysis may involve mechanisms that are also used to process nonlinguistic material.

If reception offers empirical opportunities, there are intriguing possibilities in the area of production, too. For one thing, in their effort to analyze vocalizations that convey some sort of unambiguous meaning, such as alarm calls, primatologists have frequently underplayed the "close calls" that are produced by the same animals when in friendly interactions with familiars (Harcourt et al. 1993; Silk et al. 2000). These sounds, unlike calls and grunts, may contain elements that, to the human ear, resemble speech (Richman 1980, 1987). Close calls include lip- or tongue-smacks, aspirate sounds produced during rhythmic oscillations of the mandible; and girneys, low-amplitude vocalizations that are produced more variably and frequently co-occur with smacks during grooming. Significantly, lipsmacks act like speech, too, for they are used to signal the intention to groom or, more generally, to appease (see review in Locke 2007).

If perception and production are fruitful areas of research, we can hardly ignore the possibility of interactions between these two areas. In the last few years, there has been a great deal of electrophysiological research on mirror neurons, brain cells that are activated both when an animal---most of the research has been on macaques---performs a goal-directed action,

particularly of the hands or mouth, and when it observes the same action performed by another. Some of these neurons respond to the sight and sound of specific actions, ones that make, and are therefore associated with, a particular sound (Keysers et al., 2003; Kohler et al., 2002). These findings have caused scholars to consider the possibility that spoken language evolved from, or at least was preceded by, the use of manual gestures (e.g., Arbib, 2005a,b,c; Fogassi & Ferrari, 2004). Since mirror neurons are located mainly in area F5 (in premotor cortex), investigators have not failed to notice the connection with the language processing mechanisms of humans. Arbib (2005a,b) has suggested that *Homo habilis*, and especially *Homo erectus*, had a "proto-Broca's area" that emerged from manual and oro-facial activities.

This research addresses the evolution of vocal control by looking at mechanisms and functions, but we also need to consider the role that may have been played by development. It helps, in this context, to note some recent evidence that captive chimpanzees signal in novel or unusual ways if they want something that is in the possession of a human (Hopkins et al. 2007; Russell et al. 2005). There also is evidence of innovation in immature primates. They may not innovate more than mature animals (Reader & Laland 2001), but they certainly do their share (Kawai 1965; Kawamura 1959; Pruetz & Bertolani in press; van Schaik 2004; Wrangham et al. 1996). One investigator has even raised the idea of a "critical period" for the development of a new skill (nut cracking) in chimpanzees (Matsuzawa 1996).

In nonhuman primates, it is not clear whether innovations of the young transmit vertically (Galef 1990; Hauser 1988), but there is little doubt of this in our own species (Locke in press). Several studies of vocal imitation have shown that in the first year of life, the *mother* does most of the imitating (Pawlby 1977; Uzgiris et al. 1989), possibly because this tends to attract the attention, and elevate the mood, of her infant (Meltzoff 2007). Some of these replications may also be incorporated into the speech of caregivers, and not just transiently. It has been claimed that many of the "baby words" that are used with infants---mama, dada, wawa---originated with infants and were then taken up by their observant parents (Ferguson 1964; Locke 1985, 1990). Elsewhere, I have called this "trickle up phonetics," but since baby words include bye-bye, wa-wa, pee-pee, ka-ka, and a host of other such terms, it could also be called "infant-inspired vocabulary" (Locke 2004a; 2006a; Locke & Bogin 2006).

What is important about these improvisational abilities of the young? It helps to re-visit the fact, discussed earlier, that environmental changes increased infant dependency in ancestral humans. This would have intensified the conflict between them and their mothers (Trivers 1974). When mothers withdrew their attention, it was argued, infants began to "negotiate" continued care. There are indications, in at least one group of hunter-gatherers, that infants who receive little care cry more often, and for longer durations, than other infants, and that infants fuss and cry more when their mothers are present than when they are absent (Fouts & Lamb 2005). It is relevant that earlier weaning would have shortened the inter-birth interval, enabling women to have more infants in their reproductive lifetime. This would have produced an increase in the number of siblings---competitors for care. I claim that this heightened competition, combined with unprecedented levels of helplessness, forced infants to explore clever new ways of using the voice to secure and maintain maternal proximity, and to monitor and "read" maternal feedback; and that, therefore, some of the vocal ability presupposed by spoken languages was asserted initially by hominin infants and reinforced by successful interactions with their parents. According to the proposal, infants who issued more effective care-elicitation signals received more care and lived on to reproductive age (Locke 2006a).

The evolution of more complex care signals may have got our ancestors part of the way into speech. For one thing, modern infants who babble, that is, engage in motor activity that results, perceptually, in what appear to be consonant-vowel syllables, are evaluated more favorably than infants whose vocalizations contain no syllables (Bloom et al. 1993; Bloom & Lo 1990). Infants who have various sensory and physical impairments, frequently begin to babble after the usual age and then seem to do so rarely (cf. Oller 2000). Complex vocalizations may thus act as cues to infant fitness. It also appears to be the case that in the stages of vocal development leading up to babbling, and in that activity itself, infants acquire (and certainly manifest) increasing ability to "decouple" or "emancipate" vocal activity from environmental stimulation (Oller 2004; also see Locke 2004b). The result is a system flexible enough to be used for speech, and there is evidence that vocal abilities presupposed by variegated babbling are in fact adequate for infants' initial words (Vihman et al. 1985).

We do not know if the behaviors that develop in modern stages contributed similar elements to linguistic capacity in evolution, but some parallels seem likely. In infancy, these include vocal signaling and engagement with caregivers, and interpreting the reactions of adult caregivers; and in adolescence, the use of vocal and verbal behaviors in competitions for sex and dominance. These behaviors are much in evidence in the other primates, and presumably would have had a role to play in our own ancestors, living in the "environment of evolutionary adaptedness" (EEA; Bowlby 1969). The closest equivalent to these individuals today is thought to be the hunter-gatherers in the savannas of sub-Saharan Africa (Franks 2005).[10]

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I propose that new levels of vocal complexity, flexibility, and control that emerged from infancy were carried into later ontogenetic stages where---development being continuous and cumulative---they were reinforced and elaborated.[11] In the new childhood that followed, these signaling capabilities would surely have proved beneficial, for if children are to avoid hazardous aspects of their environment, they must be warned or, better, "instructed." According to a proposal by Fitch (2004)---one of few other devo → evo accounts that exist at present---hominin parents benefited by exchanging accurate information with their offspring, and with other kin who shared their genes. The better-informed young, according to Fitch's proposal, were more likely to survive into adulthood, passing on to their own offspring genes associated with the improved system of communication.

An information-based account, of course, is one of pressures and benefits. One still needs to explain the requisite increases in symbolic and referential capacity. There surely is room for an adaptation-based proposal here, for the reproductive advantages of lexical communication in a time of intense social pressure would seem to be obvious. Perhaps it was in response to this that Bickerton (1981; also see 1985, 1990) came up with "proto-language," a small stock of words that may have been used singly or in combination with one or two others to communicate. But the evolution of language obviously did not stop there. How do we get from a handful of words to voluminous vocabularies, ones that greatly exceed perceptible functionality (Berlin 1992), and from one- and two-word utterances to longer and more fluent stretches of speech? Certain characteristics of juvenility and adolescence seem particularly relevant here, for these stages would have provided social pressures---perhaps "runaway" pressures for attractive forms of self-

expression (Harvey & Arnold 1982)---that pushed our ancestors past isolated words into longer stretches of speech (Burling 1986, 2005; Dessalles 2007; Miller 2000; Pinker & Bloom 1990).

None of these changes would have endowed hominins with grammatical skills, but they could have facilitated increases in ancestral levels of vocal complexity and control (Locke 2007b, in submission), thereby taking a small step toward phonetics, phonology, and the combinatorial privileges that enable massive vocabularies (Studdert-Kennedy 2005). Since all of the (hearing) world's languages are spoken, an evolutionary account of *language* may require specific arguments regarding *speech*---beginning with vocal imitation and oral-motor control (Arbib 2005b; Locke 1998a; Studdert-Kennedy 2005), modifications that would have antedated the evolution of grammar (Bickerton 1995, 2000). [12]

Although childhood sees increases in independence from family members, juvenility would have given the young opportunities to prepare themselves, while still sexually immature, for a stage in which vocal and verbal performance played a prominent role in the competition for precious resources---particularly sex and dominance (Locke 2001; Locke & Bogin 2006).[13] In modern juvenility, many of the language developments that occur take place beyond the sentence level, in the quality of extended discourse and narratives. New abilities in pragmatics and verbal performance facilitate a variety of socially relevant activities, from gossiping to joking and storytelling, and contribute to successful competition and courtship in the run up to sexual maturity. In adolescence, there is usually a cross-cultural increase in verbal aggression, mainly in the form of swearing and malicious gossiping, which begins at about 11 years (Björkqvist et al. 1992a, b; 1994), co-timed with endocrine changes in males and females (Granger et al. 2004).

In sexual maturity, the voice and vocal learning may have been submitted to natural and sexual selection. Recent evidence indicates that men lower their vocal frequency when speaking with a less dominant conversation partner, and raise their frequency when speaking with a more dominant one (Puts et al. 2006). So-called "Type A" individuals, who are perceptibly aggressive and primarily male (Matthews & Angulo 1980), have been found to speak with significantly greater loudness, a faster rate, and a more "plosive" quality than "Type B" individuals (Schucker & Jacobs 1977). "Plosive" means that some words, particularly the first words in a sentence or

key words, stand out as being louder than other words (also see Friedman et al. 1969). There are other categories of verbal behavior that may serve as fitness indices in males, too. These include hedges, hesitations, intensifiers, and fillers, which are negatively correlated with independent measures of social dominance in males (Erickson et al. 1978; Hosman 1989).

Miller (2000) has argued that sexual selection shaped human language directly, through mate choice, and indirectly, through its effects on social status. "Sexual flirtation during early courtship accounts for only a small percentage of language use," he admitted, "but it is the percentage with the most important evolutionary effects. This is the time when the most important reproductive decisions are made, when individuals are accepted or rejected as sexual partners on the basis of what they say." (pp. 356-357) Mate selection is also influenced by *how well* individuals speak (Locke & Bogin 2006). That the human voice may play a role in intersexual selection is suggested by some research in nonhuman primates. For example, in orangutans, often widely dispersed, there is anecdotal evidence of an association between frequency of male loud calls and frequency of female approach (Delgado 2006). In baboons, there is evidence that males that issue quiet grunts when approaching females are more likely to achieve affiliation than those who approach without vocalizing (Palombit et al. 1999).

In our own species, the speaking voice is an extremely rich repository of biologically relevant information. The fundamental frequency (F0) is inversely correlated with a range of fitness indices in adolescent and adult males, males with lower F0s having greater testis volume (Harries et al. 1997) and levels of testosterone (Dabbs & Mallinger 1999; Pedersen et al. 1986), which is positively associated with coital frequency (Halpern et al. 1998; Udry 1988). Women prefer male voices that are low in frequency (Collins 2000; Collins & Missing 2003; Feinberg et al. 2005), especially when these listeners are in the high estrogen phase of their menstrual cycle (Puts 2005). Thus it seems reasonable to suppose that hominin females who chose a male with a low voice were likely to acquire a mate who was not merely competitive, but also fertile, protective, and provident (Collins & Missing 2003; Hughes et al. 2004; Locke & Bogin 2006).

Unlike some other indices of male fitness (e.g., structural symmetry and chest-to-waist ratio), the speaking voice represents an extremely flexible way to compete for sex and status. But do

sexually mature males actually do things vocally and verbally to increase their courting success? Anolli and Ciceri (2002) found that successful (Italian) seducers began conversations by addressing their female targets with unusual levels of loudness. Then, as the conversation proceeded, the men lowered their vocal intensity and frequency, later returning to initial levels of loudness, and a faster rate of articulation---a variable that in other work has been associated with perceived competence and influence---by the end of the interaction.

It is likely, of course, that mate selection criteria have applied not just to physical activity, but to higher levels of self-expression. In a study carried out in Scotland, young adults rated the probable effectiveness of men's "chat-up lines" from printed vignettes in which men approached women with amorous intentions. The results suggested that women would respond positively to lines that revealed certain traits, e.g., helpfulness, generosity, and wealth. These traits, according to evolutionary theory, are likely to benefit women.[14] Subjects thought that jokes, empty compliments, and sexual references would not increase the men's chances of success, nor were the authors able to think of any theoretical reasons why they should (Bale et al. 2006; also see Kleinke et al. 1986).

Bickerton (2006) has questioned my conflation of linguistic content and linguistic action in previous work, but how could our ancestors have achieved an advantage over their competitors without *doing* something with words? For vocal and verbal properties to be selected, adolescents and young adults would have to compete with others, and to perform in public arenas. It seems likely that the relevant dispositions---perhaps secondary to endocrine changes---increased the functionality of vocal and verbal ability while also making it public, raising the probability that these skills would be sufficiently observable to be selected. But on what basis were they selected? We cannot transpose ourselves into the EEA, but hints are available in ethnologists' descriptions of life in oral cultures. "Verbal ability," Abrahams and Gay (1975) have reported, "can make the difference between having or not having food to eat, a place to live, clothes to wear, being accepted or rejected by one's peers, and being personally and emotionally secure or risking a complete loss of ego . . . for a member of street culture, language is not only a communicative device but also a mechanism of control and power." (p. 159)

With evidence of these links in contemporary cultures, and arguably in the EEA, one might expect a variety of associations between verbal expressivity and dominance on the one hand, and linguistic knowledge and skill on the other. Research indicates that the tendency to perform verbally is connected, theoretically and statistically, to acting and extraversion (Riggio 1986), which are positively correlated with social status (Anderson et al. 2001), testosterone (Dabbs et al. 1990; Daitzman & Zuckerman 1980; Udry & Talbert 1988), fecundity (Snyder 1987), and various social skills, including the ability to interpret nonverbal cues (Akert & Panter 1988), something that might have mattered a great deal in early stages of linguistic evolution. Extraversion at the age of two years is also positively correlated with expressive and *receptive* language at two, three, and seven years (Slomkowski et al. 1992), and similar associations have been observed between volubility---regardless of its content or complexity---and language development (Rescorla & Ratner 1996; Thal et al. 1995). Although extraverted individuals may get more practice speaking, it is also possible that, in evolution, extraversion facilitated and converged with, vocal and verbal behavior, the association remaining in evidence today.

I have placed a great deal of emphasis on adolescence as an innovative stage with reproductive advantages. The reason, in part, relates to the benefits and stresses associated with living in groups. It has been argued that group pressures preceded and played a role in the evolution of language (Dunbar 1993). The benefits of group affiliation, and the achievement of personal identity and autonomy, may have motivated adolescents to invent vocal and verbal behaviors, thereby reinforcing any improvisational abilities carried forward from previous stages. *Contemporary adolescents* do not merely learn additional linguistic features and rules of usage, but also modify material learned in earlier stages, and invent new words and constructions. In oral cultures, "new slang words are constantly created as a way of maintaining an in-group relationship and of excluding outsiders," according to Abramson and Gay (1975, p. 159), and this creativity is a force in contemporary language change (Eckert 1999; Labov 2001). But the changes are not limited to words. "The relatively high degree of phonological innovation in the adolescent age group," wrote Eckert (1988), "is an indication that the development of adolescent social structure provides a major impetus for phonological change." (p. 197)

Theoretical benefits of devo → evo to the evolution of language

Since there would have been a high degree of variation and plasticity in early stages of life history, it is likely that infancy and childhood played a special role in the evolution of language, producing new behaviors and new forms of selection. But there is a second reason why events associated with the early stages would have played a role: if vocal, and eventually vocal and verbal, behaviors of adolescents increased reproductive advantage, then all relevant developments that occurred *before* adolescence would also have played a role. Improved understanding of these developments promises to put a new light on a number of issues in which linguistics has long had a stake.

Modularity. One such issue is modularity. Modularity has been the subject of much debate, and my intention is not to revive it here, but I will suggest that EDL provides opportunities to take a fresh look at the issues. EP assumes that abilities that were repeatedly selected in the Pleistocene, including those that process faces and infer intentions, could *only* be available to us now as highly *specialized* systems (Cosmides & Tooby 2002; Kanazawa 2004). But human intelligence is not merely a collection of specialized systems. It also includes a general factor (psychologists call it *g*), one that presumably owes its existence to no specific adaptations. This general ability, now called improvisational intelligence, includes "the ability to reason deductively or inductively, think abstractly, use analogies, synthesize information, and apply it to new domains." (Kanazawa 2004, p. 514). IQ tests measure both kinds of intelligence, but there is no necessary relationship between cognitive abilities that were highly selected---and may now be modular---and ones that lack a specific adaptive account. This means, for example, that general intelligence---would not necessarily be correlated with dedicated forms of intelligence that solve specific problems, such as parenting, and there is evidence that it is not (Kanazawa 2004).

Where language is concerned, there may also be a general ability that co-exists with narrower specializations (Hauser et al. 2002). One cannot learn to speak without paying attention to people who are talking, and so we may suppose that the infant's social orientation plays a huge role in lexical learning, along with a number of perceptual, memorial, and conceptual developments. Thus it is assumed that lexical acquisition relies on mechanisms that are recruited

by nonlinguistic tasks as well. We saw this in the prosodic experiments with monkeys and humans infants reviewed earlier, and we catch a second glimpse of it in the lexical learning of other species (Savage-Rumbaugh & Lewin 1994; Fischer et al. 2004; Kaminski et al. 2004). Based on these considerations alone, it would seem that language, if any of it is modular, must be a collection of modules. There is evidence, moreover, that constituents of language that vary in their degree of grammaticality, e.g., open- and closed-class words, have their own neurodevelopmental histories---even their own critical periods (Neville et al. 2002; Weber-Fox & Neville 2002). Other components of language may also be genetically differentiated (Marcus & Fisher 2003). If systems that handle open- and closed-class words are differently sited in the brain, and remain open for different amounts of developmental time, it is reasonable to suppose that the relevant control systems are unequally specialized, and that vocabulary and grammar are unequally specialized too. In some respects, the grammatical system---which is less open to introspection and currently harder to explain as an adaptation---seems the more dedicated of the two. But it is easier to construct scenarios whereby words solved persistent problems in the Pleistocene. This disparity may fuel the argument that grammar was not an adaptation at all (Piattelli-Palmarini 1989).

Continuity. In a treatise on the embryological development of the chick, published 45 years before Darwin was born, the German biologist Caspar Friedrich Wolff wrote that "each part is first of all an effect of the preceding part, and itself becomes the cause of the following part." (Wolff 1764, in Hall 1999, p. 112) There being continuity in development, it is supposed that infants and children who achieved effective use of sound-meaning signals carried some form of the relevant control behaviors into juvenility and adolescence, where they would have enabled additional capabilities, including vocal and verbal skills that, among other things, facilitated the quest for status, sex, and additional resources.[15] The new skills were reinforced by reproductive success, which automatically strengthened---in a second or third hit---the precursors that had persisted, in some form, from earlier stages. In doing so, components and specific applications of the human voice became cues to fitness and a genetic specialization emerged, one that would figure into the development, learning, and strategic use of complex vocalizations in future generations.

There is a tie between continuity and modularity. In the past, it has been assumed that if two or more components of language were associated---or at least not dissociated---they were expressions of the same specialty, but they could also occupy separate modules that are linked. The reason is that selection operates preeminently at sexual maturity. Since development is continuous, behaviors that index fitness in early adulthood presuppose the earlier mastery of foundational behaviors. In principle, this could link late developments, such as pragmatics, and earlier acquisitions, such as phonology, and there is evidence for precisely this sort of association (Locke & Bogin 2006).

Complexity and intelligence. It has never been clear why phonologies have more phonemes than their lexicons require, lexicons have more words than the average speaker needs to know, and grammars provide complex syntactic patterns that seem communicatively inessential. Difficulty in explaining the advantage of surplus material, in informational terms, may suggest that it provided our ancestors with a quick and fairly reliable way to evaluate each other's cognitive capabilities. In the *Homo* line, it is possible that ancestors who reached limits on their ability to attract others vocally and verbally, through the quality of their performances, were forced to look for ways to increase the complexity of the underlying system.

The relationship between complexity and intelligence could also have increased incidentally, as the result of innovation. Recently, a relationship was reported, in primates and other animals, between frequency of innovation and rate of learning, or intelligence (Ramsey et al. in press). It is possible that vocal innovation is also correlated with intelligence, and has served as a fitness indicator. Doing so would have placed innovation within the reach of natural selection, and increased vocal complexity.

It is often said that speech is energetically "cheap," as though this somehow disqualifies its use as a fitness indicator. But a behavior that is unenergetic would be an excellent place to put the complexity that predicts individuals' ability to solve *cognitively challenging* problems. There were lots of ways that our ancestors could have found out who had physical energy, merely by observing day-to-day activities in a highly competitive hunting-gathering society, from the fabrication of stone tools to the procurement of wild game. But how much could they have

learned about the minds of their colleagues if the mouthpiece---speech---were "costly" in and of itself?

As discussed at the outset, work on linguistic evolution is proceeding as never before, and yet there is, and on present assumptions may continue to be, a serious obstacle to what many would consider the ultimate success. For the best of linguists have had difficulty thinking of a fitness account for grammar (Lightfoot 1991). Perhaps it is time to ask if this might be telling us something. For example, what if an early benefit of complexly patterned verbal behavior was in what it told listeners about the *speaker*? Generally speaking, the more complex the system, the harder it would be to learn and manipulate, and therefore the harder to fake.

Anthropological evidence seems to support this. In Malta, men engage in poetic duels that are so complex that those who attempt them "must be extremely intelligent." (Herndon & McLeod 1980, p. 147) Associations between verbal ability and intelligence have also been described in members of several African cultures as well as their descendants (Finnegan 1969; Peek 1981). In African American communities too, "rap" and "the dozens" permit evaluations of an individual's ability to compete and adapt. "Black culture," Kochman (1971) noted, "promotes the development and demonstration of those skills which reflect on an individual's underlying *intelligence*, verbal ability, speed, strength, agility and endurance." (p. 19, italics mine)

Recently, I suggested that verbal complexity may have played a role in mate selection (Locke in submission), since intelligence is something that females say they want in a mate (Buss 2003). If ancestral men sensed women's interest in vocal and verbal complexity, they might have attempted to display their knowledge of words or syntactic patterns, and with favorable results---in modern humans there is a positive relationship between rare words and total vocabulary, and between vocabulary size and intelligence (Carroll 1993; Gustafsson & Holmberg 1992; Gustafsson & Undheim 1996; Ullstadius et al. 2002; Vetterli & Furedy 1997).

Linkage. In evolution, direct selection for speech at sexual maturity would have indirectly selected for previous accomplishments in vocabulary and grammar. This would have linked up with the systems responsible for the later developments with the systems that produced the initial

accomplishments. There is an interdependency between lexical and grammatical development---grammar not only needs words, its development may require a certain number of words, and possibly a base level of certain kinds of words (Bates et al. 1994; Marchman & Bates 1994; Plunkett & Marchman 1993). There also is evidence that linguistic structure is correlated with pragmatics, insofar as individuals who are slow to acquire language, as conventionally tested, tend to be less responsive to listeners, less tactful, less comforting, less persuasive, less able to interpret social cues, and less able to understand jokes, slang, and sarcasm (Bishop 1989; Fujiki & Brinton 1991; Ninio et al. 1994; Nippold 1998; O'Neill 2007; Paul 1995; Prutting & Kirchner 1987).[16]

This linkage of specializations suggests that one way for theorists to approach grammar---perhaps one of the few if one is to play by evolutionary rules---is through speech. In the last few years, research has been exposing surprisingly intimate relationships between speech and other, seemingly disparate, levels of language. For example, it has been found that the frequency and complexity of vocalization by infants predicts later success in various areas of language, including comprehension (Locke 1998b; Oller 2000). In longitudinal studies carried out in three different countries it has been found that "language" problems in infancy may persist as speech, or even purely articulatory, problems in adolescence and adulthood. Findings in behavioral genetics also support links between language and speech. In studies of monozygotic and dizygotic twins, for example, the highest rates of concordance have come from twins in whom the disorder was primarily expressive---some had disorders that were purely of the articulatory type (see Locke & Bogin 2006 for references). Following reports on the English family that has had morphological problems in all three generations (Gopnik 1990; Gopnik & Crago 1991) it was reported---in a re-emphasis of earlier work that had been largely ignored---that the most consistent trait was a severe oral and verbal dyspraxia that was *accompanied* by (and possibly manifested as) deficits at other levels of language (Vargha-Khadem et al. 1995; 1998). In functional imaging studies, affected family members revealed significant underactivation of Broca's area in both hemispheres, consistent with a deficit of speech production (Liégeous et al. 2003).

The evolved trait of language. By looking for reproductive advantages to vocal and verbal behaviors, EDL shifts the emphasis from language as a static object, perhaps one whose primary benefit lies

in presumed contributions to thought, to language as a set of dynamic potentials for personal and social action. For if one is to play by neo-Darwinian rules, it is essential to locate a role for natural or sexual selection, and here it is reasonable to suppose that selection acted on public and perceptible behaviors that increased reproductive success. This can only mean that someone had to *do something* by speaking, in a social or reproductive context, something that appealed unusually to parents or to other sexually mature males and females. Does this jeopardize accounts of linguistic grammars? No. If anything, it raises questions about relationships between vocal and verbal performances and the undergirding material and systems that---among other things that they may now enable in today's societies---make such performances possible. Following this theoretical trail does not lead us astray. Indeed, if it leads us anywhere, it is to the same place that empiricism is already independently taking us now: the intersection of grammar and speech in development and in evolution.

An Evo ↔ Devo Agenda for the Future

I have proposed that linguists develop and pursue a new program of study---EDL. This will naturalize the faculty of language. By increasing ties with pragmatics and verbal performance, and generating new areas of inquiry, it will also edge the field of linguistics closer to the other natural sciences. In the end, of course, the value of any new configuration of intellectual resources lies in its potential to facilitate interpretation of existing data, and to generate interesting new questions. I hope to have made clear several ways that EDL can facilitate interpretation, and have described some of my own research. Here, mainly to illustrate additional possibilities, I will suggest a few questions that could be asked in the future.

Evo → Devo

If we are fully to understand the effects of evolution on development, we need to know more about the evolution of adolescence, including the significance of the brain changes that occur then, and the remodeling of juvenility. Juvenility appears to be a transitional stage, perhaps a time to consolidate previous gains, and to "practice" skills that will be needed in adolescence.

We are used to saying that since no osseous structures are exclusively dedicated to speech, paleontology cannot contribute much, if any, data that relate *specifically* to the evolution of speech or language.[17] Of course we do care about some general issues, such as increases in cognition, and paleontology has been massively helpful here in identifying changes in the size of the brain and cranial vault. But in an evo → devo framework, there are other possible contributions of paleontology too, for the analysis of bones and teeth provide important evidence on the evolution of developmental stages (cf. Dean et al. 2001; Smith & Tompkins 1995; Smith et al. 2007; Tardieu 1998).

We also need to know a great deal more about babbling, the highly patterned syllabic behaviors that typically begin between seven and ten months of age, when words are comprehended but not yet produced (Oller 2000). Does the onset of babbling signal the awakening of the vocal-motor system that evolved for speech, and will normally be used for that purpose several months later? Or did babbling evolve as a care-elicitation signal, which was later appropriated for more complex signaling when other changes began to produce the relevant pressures?

In traditional societies, ones unaffected by literacy and academic training, language is an intensely social business. Scholars who see language only as a code or an object whose primary value is the facilitation of thought need to ask themselves why language should be used as it so frequently is---to pass the time of day, to become familiar with strangers, to connect with friends---and should be correlated with any personality variables at all, much less variables, such as extraversion, that relate specifically to socialization.

Devo → Evo

It is essential that studies be carried out on the inventiveness of infants and children, and the degree to which their behavior diffuses horizontally and vertically. To what degree, and in what ways, are the human young evaluated and treated differently on the basis of vocal and verbal behaviors; and of primate young on the basis of their vocal behaviors? Clearly, adolescence is a linguistically creative period, and the behaviors that emerge from this stage are almost certain to survive into adulthood, with effects on cultural linguistic conventions. But to what extent is this

also true of juvenility and childhood, when verbal games, riddles, jokes, and songs---many completely unknown to parents---enjoy an unusual status, and offer social advantages to those who know them; and to what degree are these behaviors due to things that happen in infancy?

I have alluded to electrophysiological research that reveals motor-neuron activity during exposure to the intentional oral and manual gestures of others. Extensions of this research stand to improve current understandings of linguistic perception, and are already providing clues to the evolution of spoken language. But there also is room for a new program of brain studies within the EDL framework. One evo → devo example, mentioned earlier, relates to findings of substantial neural reorganization at adolescence, when there is, as it turns out, rich linguistic innovation and robust development of pragmatics and verbal performance. These or related changes may be linked to the documented role of adolescence in language change, particularly at the level of phonology.

These findings may appear strikingly disparate, but viewed through an appropriate prism---that of human life history---they begin to come together, and to enjoy further relationships with changes in the endocrine system. As for devo → evo effects, one worthwhile empirical target would be neural plasticity in relation to vocal innovation in chimpanzees, and to innovation at all levels of sound-making and language in human infants.

Research is needed on vocal and verbal behaviors that facilitate access to sex and mating relationships, and the acquisition of status. This means that we must learn a great deal more about the psychological and social reactions of sexually mature males and females to aspects of adolescent and adult males' performance of language, as well as to the content and structure of language itself. In future research, it may be fruitful to further define the relationship of rare words to vocabulary size, and the association of these variables and intelligence. We also need to know more about the fitness value of verbal humor, the ability to manipulate formulaic and colloquial material, and such measures as the loudness, rate, and fluency of speech, and the developmental systems responsible for these attributes. In line with a standard approach in biology, it would then be possible to look at which vocal and linguistic variables are most strongly linked to fitness.

Mate selection research indicates that when women appraise a man for a date, they look for different traits than they do when searching for a stable partnership (Gangestad & Simpson 2000; Kruger et al. 2003). This suggests that women may differentially evaluate vocal and linguistic cues in the context of short- and long-term mating relationships. An important area of investigation is the evolutionary origin of these perceptual and evaluative systems. A possibility that seems worth considering is the provision of infant care. In a study of young women's ratings of children's conversational speech, the highest degree of variance was accounted for by a *dynamic* factor that included the attributes: excitable, loud, uncontrolled, bold, active, uninhibited, spontaneous, assertive, and dominant. Overall, ratings were more influenced by these *speech quality* indices than sentence complexity and grammaticality (Burroughs & Tomblin 1990). It is also not unusual for mothers to display exaggerated prosodic variations when addressing their infants, especially their daughters (Kitamura & Burnham 2003). Since courting men evidently exaggerate prosody (Anolli & Ciceri 2002), it is possible that in evolution there was something of a sensory trap at work here (Christy 1995; Enquist & Arak 1993; Macias Garcia & Ramirez 2005), ancestral men mimicking vocal qualities that appeared to excite or please females in other contexts.

Studies of men's courtship speech raise a question: do men with attractive voices *need* to engage in animated vocal displays? Although linguistic knowledge is frequently differentiated from its social applications, it may be beneficial to investigate complementary relationships between the two, especially in courtship and dominance displays. One suspects that there are trade-offs between physical and behavioral factors. Perhaps individuals with less physically attractive traits produce more extravagant displays. In the avian literature, it is evident that there are many different cues to attractiveness, which interact in complex ways (Badyaev & Hill 2003; Badyaev et al. 2002; Candolin 2003; Coleman et al. 2004; Johnson 1999; van Doorn & Weissing 2004), and there is evidence, too, that physical and behavioral complexity are indirectly correlated with health (Bortolotti et al. 2006; Jawor & Breitwisch 2003; Leitão et al. 2006; Pérez-Rodríguez et al. 2006).

Concluding Remarks

To illustrate ways that development can affect evolution, I have described proposals that feature continuing selection and re-selection over the four developmental stages. In each stage, the basis of selection was assumed to differ somewhat from preceding and following stages. In all four stages, according to the proposals offered, natural (or intra-sexual) selection occurred, with sexual or (inter-sexual) selection also occurring in adolescence. Both forms would have increased the vocal and verbal complexity, and ultimately the capacity for complexity at all levels of language. The goals of EDL can and should be, at a minimum, explication of the role of evolutionary processes in the emergence of language in the human infant, and the role of developmental processes in the evolution of language in the species. This goes beyond the study of evolution, and the development of language in a biological framework. Initiatives are needed in both of these areas, but there is expected to be greater theoretical benefit from research carried out in an evo-devo framework.

I have expressed skepticism about the objectification of language---the treatment of language as little more than a grammatical code that is stored in the brain---partly because it is difficult to think of a way to achieve selection-based accounts for a mental object. But it is more important that we adopt a new theoretical framework, one that is grounded in the synergies of evolution and development. In the end, I would be happy for empiricism, carried out within such a framework, to tell us how we ought to think about human language.

I began by noting the recommendation that psychology be "naturalized," that is, conceptualized "in terms that are continuous with the natural sciences" (Franks 2003, p. 64). I conclude by suggesting that if language and linguistics are subjected to the same process, benefits will be reaped within the field, and in the other biological and cognitive sciences, for many years to come.

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Notes

[1] This does not mean that the environment can only *model* language. Cultures that promote literacy and formal education profoundly influence language, imbuing it with objective properties that are not displayed in traditional (oral) societies (Goody & Watt 1972; Linell 2005).

[2] For more details about adaptations, see Tooby and Cosmides (1990), especially pp. 384-387.

[3] Philosophers and biologists have faulted EP on several key issues, including the temptation to tell "just so" stories about the origin and adaptiveness of various behaviors (e.g., Richardson 1996). Even before EP, Gould (Gould & Lewontin 1984; Gould & Vrba 1982) leveled this charge at *all* adaptionist claims, even those relating to physical structures. Although most criticisms directed specifically to EP have been rebutted, linguists and other social scientists need to make themselves aware of what it means to "play by biological rules."

[4] Poeppel and Embick (2005) point out that since the units in brain and in language (e.g., syllables-neurons, clauses-cortical columns) are not equivalent, it is unlikely that the standard correlational approach will offer huge scientific benefits. They offer a solution that may be more promising, at least on the phonetic or phonological level.

[5] Recently, the publication of a new journal called *Biolinguistics* was announced, but at this writing the first issue has not yet appeared.

[6] A possible exception is babbling, where much of the most important work has been done by two linguists (Marilyn Vihman and Carol Stoel-Gammon) and a psycholinguist (Kim Oller).

[7] Wexler (2002) has expressed a similar view with regard to the development of computational systems; he says that once we understand these systems, we can begin to look for their supporting biology. But there is no reason why linguistic analyses cannot proceed in parallel, or in collaboration, with investigations of evolution and development, or that biolinguistic studies cannot proceed independently.

[8] An additional reason is suggested by a recent statement by Piattelli-Palmarini (2000). "The study of language is ultimately a biological science," he wrote, "but it must be conducted at a *suitably abstract level of analysis*." (p. 403, italics mine) This qualification implies a possible fear, that linguists could lose control of language as currently conceptualized if "naturalism" leads to reductionism (Bontly 2001).

[9] A new or modified stage could also, in principle, alter *preceding* stages, a possibility noted by Garstang (1928, p. 62). He said little about how this could happen, though it is apparent that selection of a trait emerging in a later stage would selectively benefit individuals arriving at the threshold of that stage with some precursive traits available, whether perceptible or not.

[10] In actuality, geographical diversification occurred at key points in evolution. As a consequence, several different hunter-gatherer environments may have played a role in human evolution (cf. Foley 1987, 1989, 1996; Maryanski & Turner 1992).

[11] The action proposed above may have facilitated the "emancipation" of vocal behavior from its earlier moorings, a process discussed by Oller in several interesting papers by Oller (e.g., Oller 2000, 2004; also see Ejiri & Masataka 2001; Iverson & Fagan 2004; Locke 2007a). For comparison, see Bickerton (2003), who treats lexical pressures as the primary force behind emergence of vocal control.

[12] Exceptionally, Corballis (2006) has claimed that gestural activity and signs preceded speech; see Locke (2007) for a discussion of the role of manual and vocal activity in development.

[13] It is likely that sound-making began in the context of symbolic communication, but there is an alternative theory---that elaborate patterns of vocalization were first manifested as song (Dunbar 2003; Fitch 2006; Merker 2000; Mithen 2005).

[14] These are the same attributes that men advertise, and that women shop for, in newspaper and magazine "want ads" (Deaux & Hanna 1984).

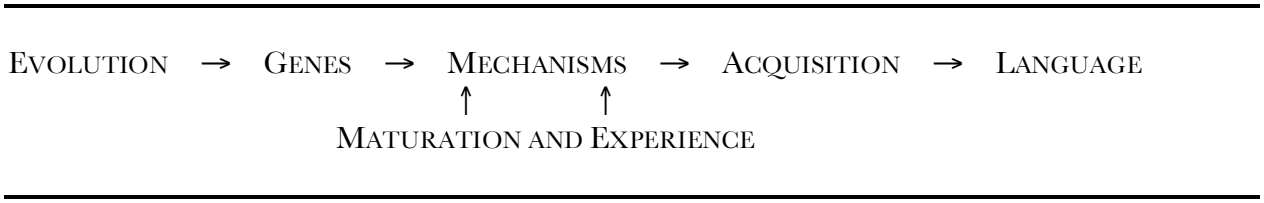
[15] Unlike linguistic continuity (cf. de Villiers 2001), developmental continuity refers to the persistence, in different forms, of traits from early stages of development into later stages and adulthood.

[16] There is abundant evidence that infants who begin to talk "on time," according to normative studies, tend to meet all other linguistic deadlines on time (Locke 1998b).

[17] Lieberman's (1985) claim that the human pharynx was selected because it produced linguistic benefits has been rendered moot by Fitch & Reby (2001), who documented descended larynges in other (nonlinguistic) species.

Footnotes

Figure 1. Development of evolved linguistic mechanisms.



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