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Book and new media reviews

Old-time linguistic theories

Authors' response to Daniel Bub's review essay of *Toward an Evolutionary Biology of Language*, ISBN 0-674-02184-3, Harvard University Press, Cambridge, MA, 2006, 441 pp., \$49.95, £32.95, €46.10.

As an undergraduate in 1950s, I was one of the four people in what must have been Noam Chomsky's first class at MIT. I went on to receive my Ph.D. in Linguistics. Chomsky's linguistic theory then seemed to provide a window into the mind. Unfortunately, as I pointed out in my 1984 book, *The Biology and Evolution of Language*, the school of linguistics founded by Chomsky became a hermetic enterprise, preoccupied with the mechanics of formal logic. Thus, my intent in writing *Toward an Evolutionary Biology of Language* was in part to move research on the nature of human language towards the principles, procedures and findings of evolutionary biology. As Theodosius Dobzansky (1973) noted, "Nothing in biology makes sense except in the light of evolution". This insight applies with equal force to understand the biological bases of human language as to understand the morphology implicated in swallowing, walking, or running.

Daniel Bub's essay, which ostensibly is a review of my book, constitutes a defense of the major claims of Noam Chomsky's linguistic theories. However, Bub does not counter the hypotheses and data in my book that bear on the issues raised in his essay.

1. Primitive and derived features of human language

My book first notes the continuity of evolution that is apparent in "primitive" features of language that we share with other creatures, and the "derived" features that differentiate human linguistic ability. Despite claims to the contrary, other living species possess some elements of human linguistic ability. Comparative studies show that Apes have limited lexical and syntactic abilities (e.g., Gardner et al., 1989). Primates communicate by means of vocal signals to a limited degree (Cheney and Seyfarth, 1980; Slocombe and Zuberbuhler, 2005). Dogs, can comprehend words without formal training (Kaminski et al., 2004). However, no other living species can form a virtually unbounded set of words and sentences by reiterating a finite set of speech sounds and syntactic processes, comprehend sentences that complex syntax, or acquire a vocabulary

exceeding tens of thousands of words. It is also the case that no other species has the creative cognitive capacities of humans, nor can any other species dance or play the violin.

2. Neural circuits and the subcortical basal ganglia

I propose that this suite of unique human attributes derives in part from Darwinian processes that modified a class of neural circuits linking cortical areas and the basal ganglia. It has become apparent that neural activity must be considered at two levels if we are to understand brain-behavior relations (Mesulam, 1990). It is evident that local operations are performed in discrete regions of the cortex and subcortical neural structures. For example, particular neural structures perform local operations involving tactile, auditory and visual stimuli. Other cortical structures perform different local operations that regulate aspects of motor control or hold information in short-term (working) memory, etc. However, observable complex behaviors such as walking, talking, or comprehending a sentence, involve local operations in many neural structures linked in a neural circuit.

It also is the case the local operation performed in a particular neural structure forms part of the linked processes in different neural circuits that each regulate different aspects of behavior. This comes about because individual neural structures generally contain many anatomically segregated groups (populations) of neurons that carry out the local operations performed in that structure. But these local processes do not in themselves constitute an observable aspect of behavior. Each neuronal population that carries out a local process is linked to (projects to) anatomically distinct neuronal populations in other regions of the brain that carry out a different local operation. The series of linked neuronal populations forms a neural "circuit", which constitutes the neural basis of an observable aspect of behavior – walking, talking, striking the keys of a computer keyboard, and so on. And a particular neural structure may play a part in different circuits that regulate different aspects of behavior because within a given neural structure, distinct neuronal populations may occur that project to neurons in different brain structures, contributing to circuits that each regulate a different aspect of behavior.

I discuss in some detail the role of the subcortical basal ganglia in these circuits. Studies of basal ganglia function

show that, the basal ganglia link sub-movements, specified by “motor pattern generators” when performing routine motor acts. The basal ganglia also play a critical role in adaptive motor acts. When circumstances dictate, the basal ganglia switch from one sequence of motor pattern generators to another, more appropriate sequence (e.g., Marsden and Obeso, 1994). The basal ganglia also support cognitive operations. Basal ganglia dysfunction in humans can result in a subcortical dementia where an afflicted individual will persevere – finding it difficult, in some cases impossible, to change the direction of a thought process (e.g., Flowers and Robertson, 1985), or comprehend the meaning of a sentence that has moderately complex syntax (e.g., Lieberman et al., 1992). And the basal ganglia are also involved in associative learning (Mireniewicz and Schultz, 1996).

For example, within the putamen, the principal output structure of the basal ganglia, anatomically segregated populations of neurons exist that form part of circuits that sequence the motor sub-movements that together constitute an overt movement of a monkey's hand, a rat's grooming sequence, or a person's walking or speaking. The putamen, in itself, is not the “seat” of these motor acts; it acts as a device that, in essence, connects the sub-movement pattern generators to motor cortex. Studies using different techniques have shown that distinct, anatomically segregated, neuronal populations in the putamen ultimately project to the supplementary motor area of the cortex and other cortical areas involved in motor control (Graybiel, 1997). Other distinct neuronal populations in the putamen are linked to ventrolateral and dorsolateral prefrontal cortex in cognitive tasks involving set-shifting in tasks such as the Wisconsin Card Sorting Test (WCST; Monchi et al., 2001). The traditional Broca–Wernicke model is at best incomplete since permanent aphasia never occurs in the absence of subcortical damage (Stuss and Benson, 1986). However, basal ganglia neuronal populations are linked to the inferior frontal gyrus in linguistic acts such as comprehending the meaning of a sentence. There is agreement on this linguistic function from researchers usually identified with the Chomskian school (Ullman, 2006). Other cortical areas are activated bilaterally during sentence comprehension (Just et al., 1996; Kotz et al., 2003).

The different activities that the basal ganglia support through independent neuronal populations in different circuits appear to reflect the mark of evolution. As Charles Darwin proposed in 1859, structures that were initially adapted to control one function take on “new” tasks in the course of evolution. In the case of the basal ganglia, a neural substrate that regulates motor control in species such as frogs has been modified in the course of evolution to take on cognitive tasks as well. One point should be clear – I do not claim that we are using motor control circuits to regulate syntax or other aspects of cognition. There are clear differences between the motor and the cognitive capabilities of humans and closely related species such as chimpanzees; one of the goals of the research agenda that I propose is to determine the functional distinctions that may differentiate the human basal ganglia “sequencing engine” from that of apes. Genetic and behavioral studies of the KE family (e.g., Vargha-Khadem et al., 2005; Lai et al., 2003; Enard et al., 2000) provide a starting

point. These studies have identified one regulatory gene, *FOXP2*, that is involved in the embryonic development of the subcortical elements of these cortical–striatal–cortical circuits. These findings suggest that enhanced human motor, cognitive and linguistic ability derives to some degree from changes in these structures and their links to cortex that occurred within the last 200,000 years.

3. Modularity and universal grammar

In short, the weight of evidence reviewed in my book suggests that the neural bases of motor control, cognition and language are commingled. I thus differ with the view held by Chomsky, Pinker and others that posits a “module” or modules of the human brain, specific to language and language alone. I also differ with the view that syntax is the key element conferring human linguistic ability and that a genetically determined neural organ – the “universal grammar” (UG) codes the range of possible syntactic operations for all languages. According to Chomskian theorists, children do not learn syntax, they instead activate rules and constraints governing syntactic rules that are already present in their brains. In other words, humans are born with preloaded syntax. The precise nature of this hypothetical neural organ has changed in the course of time from a “language acquisition device” (LAD) to UG, to its present form the “narrow faculty of language” (NFL), but the basic claim remains unchanged – that children do not learn the syntactic operations of their native languages. Children instead activate syntactic processes that are innately specified. I present evidence that argues against any form of UG – children instead appear to learn most aspects of language using the general processes employed in learning to walk or to play the violin.

4. Human speech

The contribution of speech to human linguistic ability has generally been overlooked by linguists, cognitive scientists and neuroscientists. Without speech (or sign languages invented during the past 200 years that appear to make use of neural mechanisms adapted for speech) complex language would not be possible. We otherwise would forget the beginning of a complex sentence before reaching its end. The signal advantage that human speech has over all other acoustic signals, discovered by the Haskins Laboratories research group 40 years ago, is its high data transmission rate. If you were to record and transcribe a conversation, you would need about 20–30 alphabetic characters or “phonemic” segments per second to write down the words. The high data transmission rate of speech initially seemed mysterious in the light of traditional linguistic theories which segment words into phonemes that supposedly are similar to beads on a string. The rate at which phonemes are transmitted during normal discourse exceeds the fusion frequency of the human auditory system. Nonspeech sounds merge into an indistinguishable buzz at rates exceeding 15 sounds per second. The Haskins Laboratories research program led to the understanding that we “hear” the sounds of speech by means of a complex

perceptual process that decodes an “encoded” signal in which the acoustic signals that specify individual consonants and vowels is melded (Liberman et al., 1967).

As we talk, we vary the shape of the supralaryngeal vocal tract (SVT), generating “formant frequencies”, local energy peaks in the speech frequency spectrum. The melding of the formant frequency pattern across syllables yields the high data transmission rate of speech. Recovering formant frequency patterns and phonemes from the acoustic signal involves implicit knowledge of the constraints imposed by speech producing anatomy and a subconscious appraisal of the length of airway between a person’s lips and larynx – the SVT. This capability appears to derive from an innate neural process that is used by other species to estimate the size of a conspecific (Fitch, 1997). Speech has a less obvious role when we attempt to comprehend the meaning of a sentence, or the fragments of sentences that often mark conversations. A sort of silent speech plays a part in comprehending the meanings of words and syntax (which, to a great degree, cannot be untangled) by maintaining words in the neural computational space termed “verbal working memory” (a specialized short-term memory) in which sentence comprehension takes place (Baddeley, 1986). In short, speech is an essential component of human linguistic ability.

5. Human speech producing anatomy

Although many aspects of human speech are shared with other species, humans have a species-specific upper airway that allows us to produce speech sounds such as the vowel [i] (as in the word *see*) that yield optimal calibration signals for the complex process by which we decode the merged elements that make up the stream of speech. Newborn infants have a vocal tract that is similar to those retained throughout life in nonhuman primates and most mammals. The newborn tongue and larynx are positioned in the oral cavity and the larynx can lock into the nose, forming a sealed pathway for air into the lungs. Newborn humans thus can simultaneously suckle and breathe, mother’s milk flows around the air pathway to the nose. The species-specific human SVT, the airway between larynx and lips, gradually takes shape over the first 6–8 years of life. The mouth first shortens, reducing SVTh, the horizontal mouth component, during the first 2 years of life. Throughout this period the human tongue gradually descends down into the neck changing its shape to a form having a posterior rounded shape and forming the vertical component SVTv of the vocal tract, but the process is not complete until age 6–8 years when the 1:1 proportions of the horizontal oral SVTh and vertical SVTv components of the fully human vocal tract are achieved. As the human tongue descends it carries the larynx down with it.

The advantage conferred by the human vocal tract is the ability to produce the “quantal” vowels [i], [u] and [a] (the vowels of the words *see*, *do* and *ma*). These vowels are the most frequent vowels in the languages of the world. They have formant frequency patterns that make them resistant to perceptual confusion, and also are easier to produce because they yield stable formant frequency patterns despite errors in articulation (Stevens, 1972). The vowel [i] is

a “supervowel”, providing a robust acoustic index of the length of a speaker’s vocal tract length – a factor that is necessary to perceptually decodes phonemes from the encoded flow of speech. But speech would be possible, though less effective than human speech without the quantal vowels. The selective advantage for the human vocal tract is in keeping with Charles Darwin’s conclusion that slight advantages drive natural selection.

6. Dating the evolution of fully human language

The human SVTs biological cost is death resulting from a blocked larynx. Deaths from choking are the fourth largest cause of accidental deaths in the United States. About 500,000 Americans suffer from swallowing disorders (dysphagia). There would have been no reason for retaining the mutations that resulted in the human SVT, unless speech already was in place in hominids ancestral to humans before the evolution of the human SVT. Thus, a human SVT in a fossil hominid is an index for neural circuits that could freely sequence the complex gestures necessary to produce speech. And if that brain was similar to ours, we can infer the capabilities for complex syntax and one of the hallmarks of intelligence – cognitive flexibility.

The date at which fully human brains existed can be established if we take account of swallowing. The swallowing “pattern generator” – the movements that are involved in swallowing are similar in humans and apes. When we swallow, the hyoid which supports the larynx, moves upwards and forwards, into a position in which food will not fall into it while swallowing. A larynx in the neck can execute these maneuvers. However, if the larynx was in the chest, the sternum bone would block these maneuvers and eating would not be possible. We, therefore, can conclude that no hominid descended from the common ancestor of apes and humans could have had a larynx in its chest. This makes it possible to determine whether Neanderthals and other fossil hominids could have had 1:1 SVTh to SVTv proportions by examining the bases of their skulls, which provide a measure of SVTh and their cervical vertebrae, which provides a measure of the length of their necks. McCarthy et al. (in press) determined these metrics for a large sample of chimpanzees and contemporary humans, fossil hominids believed to be ancestral to humans, and Neanderthals. Neanderthal neck lengths were too short to have fully human SVTs. The short neck and long Neanderthal mouth which determine SVTh would place the larynx behind the sternum if he had fully human speech capabilities. The resulting hypothetical Neanderthal would be unable to eat. Surprisingly, a similar constraint rules out a fully human SVT in the 90,000 year-old Skhul V fossil which has often been thought to be fully modern. Fully modern speech anatomy is not evident in the fossil record until the Upper Paleolithic, about 50,000 years ago. This time frame coincides the appearance of the tool kit and artifacts that are often associated with modern human cognitive capacities. Since many of these artifacts appear much earlier in Africa, it is probably the case that the neural bases for cognition and language that we have discussed as well as the bases for

enhanced lexical ability have a gradual, earlier origin. But the presence of modern human vocal tracts, increasing the risk of death by choking, 50,000 years ago in the an index for the presence of neural circuits capable of acquiring and reiterating the motor commands necessary for speech production. These neural capabilities would also confer syntactic and cognitive abilities. In short, the neural capacity expressed in syntax and other aspects of language is not restricted to language alone. The archeological record suggests that this was the case.

7. Daniel Bub's review

7.1. Motor control and syntax

My claim for neural circuits regulating motor control being a starting point for the evolution of circuits regulating syntax rests on the findings of the studies discussed in *Toward an Evolutionary Biology of Language*. My hypotheses do not rest on Lashley's 1951 comments. Bub overlooks my discussion of the findings of "experiments-in-nature", such as Broca's aphasia, focal lesions of the basal ganglia, hypoxia, developmental verbal apraxia, Parkinson's disease, and point mutations of the *FOXP2* gene, neuroimaging, ERP, and behavioral studies of neurologically intact human subjects and comparative studies of other species. Bub simply ignores this body of evidence and instead cites Lashley's doubts and the assertions of Pinker and Bloom (1990) paper.

The Pinker and Bloom paper, which equated the evolution of syntax with language, is marked by the absence of any supporting data. Pinker and Bloom supposedly "opened" the study of the evolution of language when they stated that human syntactic capability had evolved contrary to Noam Chomsky's negative views on that possibility. However, Pinker and Bloom retain Chomsky's views on syntax. Syntax supposedly has arbitrary properties that cannot be explained by natural selection. Darwinian natural selection does not act on nonadaptive features and one of the arguments made against natural selection shaping human linguistic ability is the hypothetical presence of "nonfunctional aspects of syntax". The title of Pinker and Bloom (1990) paper might have best been "Natural language and supernatural selection" rather than "Natural language and natural selection". Hence, Pinker and Bloom comment that "derived nonadaptive characteristics must be shared by motor control and syntax if any connection between these capacities existed".

A reading of *On the origin of species* appears to be in order for Bub as well as Pinker and Bloom. Darwin was aware of the fact that abrupt transitions occurred in the course of evolution – he invoked a two stage process to account for these transitions – chance followed by natural selection. Organs might by chance support life in a different ecosystem, providing the basis for an abrupt transition such as that from aquatic to terrestrial life. This involved, in Darwin's view, the swim bladders of fish taking on a new respiratory role as lungs, and subsequent natural selection for example modifications of the larynx from an organ that protected the lungs to an organ that also generated an efficient sound source for vocal communication. The changes were all, in

balance, *adaptive* increasing the likelihood of surviving progeny. Pinker and Bloom instead claim that the evolution of language was nonadaptive resulting in arbitrary syntactic rules.

Bub also notes Lashley's uncertainties concerning the formal structure of syntax and motor control. However, Bub neglects to take account of the discussion in Chapter 7 of my book of the similar selectional constraints and hierarchical structures of motor control and syntax. Motor control does not simply involve sequencing a series of sub-movements. Selectional constraints similar to those that mark syntactic operations apply to motor control. For example, walking involves heel strike which cannot occur before your foot has flexed as it meets the ground. Individual motor gestures must be modified in particular contexts in much the same manner as words are modified to convey different meanings in languages such as Latin. Respiratory control while talking entails long-distance constraints as complex as syntax. The "programming" by which the intercostals and abdominal muscle gradually oppose the elastic collapse of the lungs must take into account the length of a sentence *before* a single sound is uttered (Lieberman, 1984). Respiratory control during speech thus is arguably as complex as syntactic operations such as case marking, forming regular plurals, or the regular past tense. Moreover, any sequence of algorithms involving selectional constraints inherently will yield a hierarchical structure similar to the syntactic "trees" employed by linguists. In short, there is more to motor control than simply reordering a finite number of elements to achieve a potentially infinite number of creative "new" sentences, dances, athletic feats, and so on. These aspects of motor control generally are not appreciated by linguists.

Bub's extended quotation of Rene Descartes's views on language is useful insofar as it reveals the foundations of Chomsky's and apparently Bub's views concerning the uniqueness of human language. Descartes believed that language is man's alone. However, this belief carries the same weight in any scientific enquiry as Descartes's views concerning the soul.

7.2. Chimpanzee language

The primitive features of human language can be discerned by establishing whether they are present or can be attained in other species. As I note in my book, it is becoming evident that many of the phonetic contrasts that convey information in human speech are used by other species. The formant frequency patterns that encode the consonants and vowels of human speech convey both referential and emotional information in nonhuman primate vocal communications. Formant frequencies patterns also provide a means of signaling an animal's size to a conspecific. Human speech perception makes use of similar processes to take into account the effect of vocal tract length on formant frequency patterns during speech perception. These aspects of animal communicative ability do not seem to arouse linguists.

However, the fur flies when the subject changes to the "higher" aspects of language that are the subject of traditional linguistic enquiry – words and syntax. Any vestige of syntactic ability in an ape counters one of the central claims of the Chomskian school of linguistics, the UG that hypothetically

allows human children to acquire language. Chomsky has repeatedly claimed that only humans possess this ability. Chomsky is quite clear on this point.

It is a reasonable surmise, I think, that there is no structure similar to UG in nonhuman organisms and that the capacity for free, appropriate, and creative use of language as an expression of thought, with the means provided by the language faculty, is also a distinctive feature of the human species, having no significant analogue elsewhere (Chomsky, 1975, p. 40).

The chimpanzee cross-fostering experiments of Beatrix and Alan Gardner were not aimed at demonstrating that apes had fully human linguistic abilities. The Gardners placed infant chimpanzees in circumstances that approximated the 1960s home environments of middle class American children, except for using American sign language (ASL) rather than spoken English. We know that cognitively intact children will acquire language in these circumstances. By placing chimpanzees in a similar environment, the Gardners' hoped to establish the aspects of language that could be acquired by chimpanzees using their inherent biological capacities. The Gardners documented their study with filmed records. Disinterested scholars having expert knowledge of ASL such as William Stokoe, observed and conversed with the chimpanzees, Documentary film crews photographed unrehearsed human-chimpanzee conversations. Papers were published in peer-reviewed journals (e.g. Gardner and Gardner, 1973, 1984; Gardner et al., 1989). I discussed the Gardner studies in some detail as well as the subsequent replication of much of their work using computer keyboards by Savage-Rumbaugh et al. (1985, 1986) and Savage-Rumbaugh and Rumbaugh (1993).

The general finding was that, aside from being unable to talk, chimpanzees do not progress beyond the linguistic ability of a 2–3 year-old child. They can acquire and produce about 150 words and can form new words and extend the semantic referents of words. They use their active vocabulary to spontaneously converse with humans and to each other, they seem to think using words, signing to themselves as the view picture books when they are alone. Their passive vocabulary appears to be much larger than their active vocabulary and they can understand spoken English sentences that have simple syntax. Deborah and Roger Fouts in a later study showed that an infant chimpanzee could attain this same degree of linguistic ability when he was in contact with the Gardner chimpanzees communicating with each other and him using ASL (Fouts et al., 1989).

Bub nonetheless takes the position of Descartes and Chomsky and disputes the apparent linguistic abilities of these chimpanzees, though he fails to note why the findings that I reported were erroneous. In rejecting the premise that chimpanzees have limited linguistic capacities, Bub relies on Herbert Terrace who supposedly demonstrated that the Gardners' studies had no merit whatsoever. Bub writes, "My understanding of the paper by Terrace et al. is that it represents a very detailed and cogent methodological critique of some of the pitfalls inherent in assuming that the signs learned by chimpanzees have the same psychological content, at least in rudimentary form, as the words humans use in sentences".

Terrace's "critique" is a travesty. Terrace claimed that the Gardner chimpanzees simply repeated the ASL signing of their human companions when they conversed. However, Terrace's operational definition of repetition if applied to any human conversing with a human partner would classify anything spoken in response to any speech act as a repetition. Terrace classified any chimpanzee ASL signing as a repetition in response to any ASL sequence produced by a human companion. Thus the chimpanzee Washoe signing *baby* in response to her human companion signing *What's in your cup?* was classified as a repetition in Terrace's analysis.

Bub accepts and quotes my characterization of Terrace's criterion for repetition without apparently reflecting on the consequences of Terrace's repetition paradigm. If a chimpanzee signed back to his or her human companion using any ASL sign sequence whatsoever, the chimpanzee can be said to be simply imitating his human companion and has no linguistic competence, than we would arrive at a similar conclusion if we were to perform a Terrace style analysis of Daniel Bub's conversations. Bub somehow does not see the absurdity of Terrace's analysis.

Ignoring the filmed records of Savage-Rumbaugh's chimpanzees responding to spoken English requests or the Gardner chimpanzees using aspects of the inflectional system of ASL, Bub asserts, "that there is little to support the claim that they [chimpanzees] have any grasp of syntax". The primary research papers and filmed records of the chimpanzee language projects present a different picture. Chimpanzees clearly do not achieve adult human syntactic and lexical competence, but that is not the issue. We can conclude that some aspects of human linguistic ability have a "primitive" status and can be traced back to other species and presumably to the common ancestor of humans and present day apes. This argues against "protolanguages" lacking syntax of the type proposed by Calvin and Bickerton (2000). Calvin and Bickerton in this book, which Bub cites as a review of past efforts to account for the evolution of human language, attempt to marry Bickerton's Chomskian stance with Calvin's view that language derived from being able to accurately and forcefully throw objects at adversaries and prey.

7.3. UG

Bub "now understands that UG refers neither to an innately specified grammar or an abstract grammar that is universal among languages". However, that "understanding" of UG does not address the inherent biological implausibility of any form of UG. If UG simply referred to an unspecified neural substrate that allowed a child to acquire language, there would be no dispute. However, UG carries more freight. It is as Bub notes, domain specific and specifies the features of grammar that can occur in all human language. For more than a decade, the hypothetical UG specified the complex set of hundreds of principles and parameters of Chomsky's 1981 theory. UG then took the form of negative constraints in "optimality" theories. Chomsky's most recent incarnation is the Hauser et al. (2002) NFL and a lexicon that provides indices that guide the application of the critical operation that rewrites sentences that have been recursively inserted into the frame of a "master" sentence into the words that a person

actually hears or reads. All versions of UG boil down to the claim that humans have genetically specified knowledge of the possible range of syntactic operations of all human languages. The claim made by linguists is that children otherwise would not be able to acquire the complex rules of syntax of any language.

Although Noam Chomsky in a letter stated that he never reads anything that I write, the argument in my 1984 book, *The Biology and Evolution of Language* on genetic variation ruling out a detailed UG specifying hundreds of principles and parameters, may have been heeded. In his talk at the 2005 Morris Symposium on the Evolution of Language, held at the State University of New York at Stony Brook, Massimo Piattelli-Palmarini who is one of Chomsky's closest adherents, declared he had recently concluded that UG was implausible. The geneticists whom he had consulted confirmed the ever-present nature of variation, ruling out UG.

The discussion of variation and natural selection on pages 347–354 of my book addresses the implausibility of UG. As Darwin noted variation is the feedstock for natural selection. Well attested examples of natural selection acting on the pool of variation present in human populations now exist. For example, natural selection for life at extreme altitudes has yielded an enhanced ability to deliver oxygen to the bloodstream in Tibetan populations. In human populations living at low altitudes, order of magnitude differences marks the degree to which an individual has to transfer air into his or her lungs in order to transfer the same amount of oxygen into the bloodstream. Some individuals must breathe more than 10 l in and out of their lungs each minute to extract the same amount of oxygen into their bloodstream as other individuals can with only 1 l of air. Over the course of 40,000 years, natural selection acting on this pool of variation has resulted in virtually all Tibetans having this capability (Moore et al., 1998). Tibetans who are the children of parents who emigrated from Tibet and now live at low altitudes, retain this capability, which clearly is part of their genetic endowment. Forty thousand years of life at extreme altitude provided an ecological niche in which natural selection acted on the existing pool of genetic variation. Given the importance of language we surely would expect to find similar selectional pressures that facilitated acquiring Tibetan at the expense of English, if the ability to acquire the syntactic operations of a language derived from an innate UG. But it is the case that any normal child, from any ethnic background will acquire the language in which she or he is immersed in the first 5 years of life, including the ethnically Tibetan children residing close to Chomsky's office at MIT whose dialect of English does not differ from that of other natives of Central Square.

We do not have appeal to studies of genetic variation involving respiration and Tibetans. Color deficiencies and color blindness are familiar examples of behavioral deficits arising from the pool of genetic variation present in all human populations. Genetic variation is commonplace. If a UG existed, we would expect to find individuals who could not acquire some specific aspects of syntax, while having no difficulty with other aspects of syntax. We all do not inherit the same genes for anything. If a UG actually existed, we would expect to find children who could acquire Latin or German, but who never could acquire English because some genes were missing. We

might find individuals who lacked the gene or genes that regulated the English plural rule, but who could handle other aspects of English syntax. I pointed that out in a debate with Steven Pinker in 1986; Pinker's (1994) claim that a "language gene" existed was based on the erroneous report that the afflicted individuals in the KE family that had a defective version of the FOXP2 gene, lacked regular plurals and past tenses, but otherwise had normal syntax (Gopnik and Crago, 1991). That turned out to be erroneous – the KE family members having the defective gene had as noted earlier a suite of cognitive, motor and general syntactic deficits (Vargha-Khadem et al., 2005).

However, Bub seems to believe that my argument is irrelevant because the examples of variation that I cite do not involve cortical variation. It is difficult to understand Bub's position when he states that an, "appeal to the heritability of color mechanisms in the eye is surely not a guide for assessing claims about innate elements of grammar". Does Bub believe that contrary to all other aspects of morphology, "cortical" variation does not occur? Has he read my discussion of the FOXP2 gene and the syntactic deficits of the members of the KE family who have an anomalous version of this regulatory gene? The FOXP2 gene was isolated through study of the KE family. Bub may be ignoring the FOXP2 studies because the gene governs the embryonic development of the basal ganglia and other subcortical structures that support neural circuits regulating motor control, the comprehension of and other aspects of cognition.

However, apart from the fact that the retina is generally regarded as an extension of the cortex, cortical variation is an accepted fact that bears on the interpretation of fMRI studies, an issue which Bub discusses in his essay. As Devlin and Poldrack (2007) point out, many of the problems that arise when comparing the results of different fMRI studies arise from variation that is apparent in both anatomical landmarks visible in structural MRIs and at the level of microstructure.

7.4. Essentialism

In claiming that Chomsky's theories are not essentialist, Bub makes use of the same device that makes it impossible to test Chomsky's theories. Bub invokes a mysterious concept termed, "lawful variation". Variation is variation – Bub's invoking "lawful" variation brings to mind the dodge invoked by linguists to reject experimental findings that refute the predictions of linguistic theories. Data that are not consistent with the theory reflect "performance" rather than "competence". I first encountered this distinction many years ago when well attested "crucial" behavioral data that demonstrated the psychological reality of Chomsky's 1957 theory suddenly became "trivial and uninteresting" performance effects. The 1957 theory had been abandoned. Lacking an Orwellian "Ministry of Truth" that would destroy all traces of the 1957 theory, data that appeared to support the 1957 theory's predictions suddenly became irrelevant. As the philosopher of science Bunge (1984) has noted, linguistic theories are tested against theories of data rather than data.

How does Bub propose to distinguish "lawful" variation from unlawful variation? Indeed, what in earth is "lawful variation"? It is difficult to find current intellectual enterprises that are as rooted in essentialist concepts as Chomsky's

linguistic theories which attempt to describe the “competence” rather than the “performance” of an “ideal speaker-hearer”.

7.5. The lexicon

Bub uses the term “naïve” to characterize investigators who are using brain imaging techniques such as fMRI to explore the neural bases of the lexicon. It is quite true that as Bub notes, that the “meaning” that we attach to words such as “honor” cannot be mapped in any direct manner to the cortical areas directly involved in perception or action. However, in my view, the argument that Bub presents is naïve. Bub accepts traditional semantic theories despite their complete failure to characterize the meaning of even simple words such as *table*, *dog* or *piano*. I briefly discuss these problems. In brief, the predicate logic employed in linguistic semantic theories fails to capture the meaning of even a simple word which varies with context and circumstance. Scholars trained in formal logic such as Jacob Bronowski pointed out these deficiencies 50 years ago. I quoted Bronowski (1978) who noted that it is impossible to define the word *table* in terms of a set of discrete primitive elements. Aside from the question of determining the primitives (most seem to be the result of 10 min thought over lunch), when you finish defining the word *table*, someone can easily use the table as a chair. Linguistic semantic theory boils down to a word game in which words are “defined” by sets of other words. For example, *bachelor* can be defined as +animate, +human, +male, +unmarried, etc. But you then have to “define” *unmarried*, *male*, *human*, using another set of words that must then be defined, and so on. When you finish the exercise, you still will not have the foggiest notion of how a word is represented in the human brain, or the brain of a chimpanzee or a dog.

The store of meanings associated with a word perhaps derives from a family of memory traces that reflect life’s experiences and our store of knowledge concerning the world. As we activate the neural networks that characterize the meaning of a word, these memory traces surface. As I think about the word *bicycle* inevitably an image of my father steadying me on one of my first attempts to ride a bicycle emerges. As I pointed out in my book, we are nowhere near a solution to characterizing the neural operations underlying these memory traces. How these processes can be modeled and related to neurophysiology is an open question. But it is clear that formal logic invoking “primitives” such as *animate*, *human*, *unmarried*, to characterize the meaning of a word such as *bachelor* or *legs*, *flat surface* to characterize *table* does not suffice. The Greek philosophers of the classical age who attempted to characterize many phenomena in terms of “primitives”, were unable to image the brain. They probably would have jumped at the chance to conduct fMRI studies. Bub misses the point of current studies that are attempting to discern the neural bases of the brain’s dictionary.

7.6. Phonetic features and the hermetic nature of formal linguistics

The deficiencies of formal linguistics are not limited to quasi-biological claims such as UG, or semantic theories that reflect

the state of human knowledge in ancient Greece. A hermetic disavowal of the physiology of speech production and the acoustic parameters that specify the sounds of speech pervades phonology – the study of the relationships and processes that hold between words and sounds. As Chapter 7 of my book notes, the traditional linguistic theory that specifies vowels using “binary features” that code hypothetical tongue positions has been shown to be wrong in independent studies that date back to Russell (1928). Vowels instead are specified by acoustic formant frequency patterns (Nearey, 1979). A formant frequency “space” defines the vowels of a particular dialect and shifts of vowels in this space can account for the vowel shifts that have occurred in many languages. However, despite repeated attempts by many speech scientists and some linguists to point out the deficiencies of the traditional tongue position theory nothing happens (Lieberman, 2005).

7.7. Neural circuit models and variation

Circuit models explain many of the phenomena that Bub discusses in his essay. In neurodegenerative diseases such as Parkinson’s disease, it is common to find that one patient may suffer motor control problems without serious cognitive impairment, while a second patient having the same level of motor difficulty may have severe difficulties shifting cognitive sets. As Bub notes, similar differences are evident when aphasic patients are studied. The probable basis for many of these differences rests in the anatomical segregation of neuronal populations in different parts of the brain. The locus of brain damage may not hit the same segregated neuronal populations in different patients, thus different neural circuits may be disrupted in different patients; (c.f. Lieberman, 2006).

7.8. Recursion versus reiteration

Bub is completely off the mark when he states that “the most questionable part of this flawed but crucial section in the book [my argument against an innate universal grammar] lies in a resolute commitment to explaining one particular aspect of syntax ...” entirely on recursion, identified by Hauser et al. (2002) as “an abstract core of computational operations, central to language”.

Bub instead endorses the approach taken by Jackendoff and Pinker which instead argues that “grammatical knowledge is contained in stored elements of various sizes ...” such as, “... noun phrase, verb phrase”. In point of fact, I agree with Jackendoff and Pinker on this matter. I argue against recursion being the central property of syntax. I instead propose a process of reiteration that differs profoundly from Chomsky’s Minimalist theory’s view of recursion. My stand on this matter is evident on the second page of my book where I state that, “Reiteration yields the ability to insert adjectives, adverbs, relative clauses, prepositional clauses, and other types of clauses into sentences”. The distinction between reiteration and recursion is discussed in detail on pages 356–359 of Chapter 7 where I reject the role of recursion and the Minimalist Theory’s NFL. Recursion also accounts for the productive quality of phonology, syntax, music and dance.

7.9. A concluding comment

Technical jargon is sometimes inevitable. However, discussions of syntax and phonology in the Chomskian tradition are generally so opaque and convoluted as to be incomprehensible to anyone outside the discipline. This can lead to the conclusion that anything so complex must be profound. In turn, such apparent profundity encourages accepting constructs that otherwise might be viewed with skepticism such as an innate UG. However, the complexities of linguistic theories may reflect their reliance on serial algorithmic operations that are inadequate to describe natural languages (Croft, 1991) and a tendency to accept as fact, false concepts that fit the postulated theory, such as the tongue maneuvers involved in vowel production noted above. If theoretical linguists were actually able to specify the syntax or phonology of any language by means of the serial algorithms, the rules and processes that they invoke, the complexities which render their theories opaque to others might be justified. However, no present linguistic theory can even describe more than a small fraction of the syntax or phonology of any language. Indeed, theoretical linguists following Chomsky such as Jackendoff, note that, “Thousands of linguists throughout the world have been trying for decades to figure out the principles behind the grammatical patterns of various language But any linguist will tell you that we are nowhere near the mental grammar for any language” (Jackendoff, 1994, p. 26).

Studies of language that make use of scientific procedures have been viewed as somehow less exalted than theoretical enquiries based on introspection. In this world-view, philosophical enquiry providing plans for devices that journeymen mechanics will diligently construct. Successful experiments are ones that support theories reflecting linguistic competence; data that refute a theory are production effects that can be ignored. It is time to actually study the biology of language. And as Dobzhansky (1973) pointed out, “Nothing in biology makes sense except in the light of evolution”.

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