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The faculty of language: what's special about it?[☆]

Steven Pinker[a,*], Ray Jackendoff[b]

[a]*Department of Psychology, Harvard University, William James Hall, Cambridge, MA 02138, USA*
[b]*Department of Psychology, Brandeis University, Waltham, MA 02454, USA*

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Abstract

We examine the question of which aspects of language are uniquely human and uniquely linguistic in light of recent suggestions by Hauser, Chomsky, and Fitch that the only such aspect is syntactic recursion, the rest of language being either specific to humans but not to language (e.g. words and concepts) or not specific to humans (e.g. speech perception). We find the hypothesis problematic. It ignores the many aspects of grammar that are not recursive, such as phonology, morphology, case, agreement, and many properties of words. It is inconsistent with the anatomy and neural control of the human vocal tract. And it is weakened by experiments suggesting that speech perception cannot be reduced to primate audition, that word learning cannot be reduced to fact learning, and that at least one gene involved in speech and language was evolutionarily selected in the human lineage but is not specific to recursion. The recursion-only claim, we suggest, is motivated by Chomsky's recent approach to syntax, the Minimalist Program, which de-emphasizes the same aspects of language. The approach, however, is sufficiently problematic that it cannot be used to support claims about evolution. We contest related arguments that language is not an adaptation, namely that it is "perfect," non-redundant, unusable in any partial form, and badly designed for

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* Corresponding author.
E-mail addresses: pinker@wjh.harvard.edu (S. Pinker), jackendoff@brandeis.edu (R. Jackendoff).

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communication. The hypothesis that language is a complex adaptation for communication which evolved piecemeal avoids all these problems.

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1. The issue of what is special to language

The most fundamental question in the study of the human language faculty is its place in the natural world: what kind of biological system it is, and how it relates to other systems in our own species and others. This question embraces a number of more specific ones (Osherson & Wasow, 1976). The first is which aspects of the faculty are learned from environmental input and which aspects arise from the innate design of the brain (including the ability to learn the learned parts). To take a clear example, the fact that a canine pet is called *dog* in English but *chien* in French is learned, but the fact that words can be learned at all hinges on the predisposition of children to interpret the noises made by others as meaningful signals.

A second question is what parts of a person's language ability (learned or built-in) are specific to language and what parts belong to more general abilities. Words, for example, are specifically a part of language, but the use of the lungs and the vocal cords, although necessary for spoken language, are not limited to language. The answers to this question will often not be dichotomous. The vocal tract, for example, is clearly not exclusively used for language, yet in the course of human evolution it may have been tuned to subserve language at the expense of other functions such as breathing and swallowing.

A third question is which aspects of the language capacity are uniquely human, and which are shared with other groups of animals, either homologously, by inheritance from a common ancestor, or analogously, by adaptation to a common function. This dimension cuts across the others. The system of sound distinctions found in human languages is both specific to language and uniquely human (partly because of the unique anatomy of the human vocal tract). The sensitive period for learning language may be specific to certain aspects of language, but it has analogues in developmental phenomena throughout the animal kingdom, most notably bird song. The capacity for forming concepts is necessary for language, as it provides the system of meaning that language expresses, but it is not specific to language: it is also used in reasoning about the world. And since other primates engage in such reasoning, it is not uniquely human (though parts of it may be). As with the first two questions, answers will seldom be dichotomous. They will often specify mixtures of shared and unique attributes, reflecting the evolutionary process in which an ancestral primate design was retained, modified, augmented, or lost in the human lineage. Answers to this question have clear implications for the evolution of language. If the language faculty has many features that are specific to language itself, it would suggest that the faculty was a target of natural selection. But if represents a minor extension of capacities that existed in the ancestral primate lineage, it could be the result of a chance mutation that became fixed in the species through drift or other non-adaptive evolutionary mechanisms (Pinker & Bloom, 1990).

In a recent article in *Science*, Hauser, Chomsky, and Fitch (2002) offer a hypothesis about what is special about language, with reflections on its evolutionary genesis. The article (henceforth HCF) has attracted much attention both in the popular press (Kenneally, 2003; Wade, 2003) and among other language scientists. HCF differentiate (as we do) between aspects of language that are special to language (the "Narrow Language Faculty" or FLN) and the faculty of language in its entirety, including parts that are shared with other psychological abilities (the "Broad Language Faculty" or FLB). The abstract of HCF makes the very strong proposal that the narrow language faculty "only includes recursion and is the only uniquely human component of the faculty of language." (Recursion refers to a procedure that calls itself, or to a constituent that contains a constituent of the same kind).[1] In the article itself, the starkness of this hypothesis is mitigated only slightly. The authors suggest that "most, if not all, of FLB is based on mechanisms shared with non-human animals…. In contrast, we suggest that FLN—the computational mechanism of recursion—is recently evolved and unique to our species" (p. 1573). Similarly (p. 1573), "We propose in this hypothesis that FLN comprises only the core computational mechanisms of recursion as they appear in narrow syntax and the mappings to the interfaces" (i.e. the interfaces with mechanisms of speech perception, speech production, conceptual knowledge, and intentions).[2]

In other words, HCF are suggesting that recursion is the mechanism responsible for everything that distinguishes language both from other human capacities and from the capacities of animals. (These assertions are largely independent: there may be parts of the narrow language faculty other than recursion even if the narrow faculty is the only part that is uniquely human; and the narrow faculty might consist only of recursion even if parts of the broad faculty are uniquely human as well). The authors go on to speculate that the recursion mechanism, defining what is special about language, may not even have evolved for language itself but for other cognitive abilities such as navigation, number, or social relationships.

[1] Theoretical computer scientists often distinguish between *tail recursion* and *true recursion*. Roughly, in tail recursion, a procedure invokes another instance of itself as a final step (or, in the context of language, a constituent an identical kind of constituent at its periphery). In true recursion, a procedure invokes an instance of itself in mid-computation and then must resume the original procedure from where it left off (or a constituent has an identical kind of constituent embedded inside it). True recursion requires a computational device with a stack of pointers (or an equivalent mechanism) to keep track of where to return after an embedded procedure has been executed. Tail recursion can be mimicked (at least in input–output behavior or "weak generative capacity") by a computational device that implements simple iteration, where one instance of a procedure can be completed and forgotten by the time the next instance has begun. Tail recursion, however, cannot be mimicked by iteration when it comes to computations that require more than duplicating input–output behavior ("strong generative capacity"), such as inferences that depend on the grouping and labeling of constituents.

[2] It is possible to parse this sentence as saying that FLN consists of recursion *and*, *in addition*, the mappings to the interfaces, rather than recursion *as it appears* in the mappings to the interfaces. But this interpretation is more strained, and is inconsistent with the preceding two quotations, which simply identify the narrow language faculty with recursion.

HCF's hypothesis appears to be a radical departure from Chomsky's earlier position that language is a complex ability for which the human brain, and only the human brain, is specialized:

> A human language is a system of remarkable complexity. To come to know a human language would be an extraordinary intellectual achievement for a creature not specifically designed to accomplish this task. A normal child acquires this knowledge on relatively slight exposure and without specific training. He can then quite effortlessly make use of an intricate structure of specific rules and guiding principles to convey his thoughts and feelings to others, arousing in them novel ideas and subtle perceptions and judgments (Chomsky, 1975, p. 4).

Similarly, Chomsky's frequent use of the terms "language faculty" and "mental organ"[3] underscore his belief that language is distinct from other cognitive abilities, and therefore distinct from the abilities of species that share those abilities but lack the ability to acquire languages. For example:

> It would be surprising indeed if we were to find that the principles governing [linguistic] phenomena are operative in other cognitive systems, although there might be certain loose analogies, perhaps in terms of figure and ground, or properties of memory, as we see when the relevant principles are made explicit. Such examples illustrate … that there is good reason to suppose that the functioning of the language faculty is guided by special principles specific to this domain … (Chomsky, 1980, p. 44).

Indeed, the position that very little is special to language, and that the special bits are minor modifications of other cognitive processes, is one that Chomsky's strongest critics have counterposed to his for years. Not surprisingly, many have viewed the *Science* paper as a major recantation (e.g. Goldberg, 2003).

The HCF paper presents us with an opportunity to reexamine the question of what is special about language. As HCF note (p. 1572), the two of us have advanced a position rather different from theirs, namely that the language faculty, like other biological systems showing signs of complex adaptive design (Dawkins, 1986; Williams, 1966), is a system of co-adapted traits that evolved by natural selection (Jackendoff, 1992, 1994, 2002; Pinker, 1994b, 2003; Pinker & Bloom, 1990). Specifically, the language faculty evolved in the human lineage for the communication of complex propositions. HCF contrast this idea with their recursion-only hypothesis, which "has the interesting effect of nullifying the argument from design, and thus rendering the status of FLN as an adaptation open to question" (p. 1573).

In this paper we analyze HCF's recursion-only hypothesis, and conclude that it is hard to sustain. We will show that there is considerably more of language that is special, though still, we think, a plausible product of the processes of evolution. We will assess the key bodies of evidence, coming to a different reading from HCF's, and then consider how they arrived at their position.

[3] "We may usefully think of the language faculty, the number faculty, and others, as 'mental organs,' analogous to the heart or the visual system or the system of motor coordination and planning" (Chomsky, 1980, p. 39).

Despite our disagreements over the recursion-only hypothesis, there is much in the paper with which we are sympathetic. We agree that it is conceptually useful to distinguish between the language faculty in its broad and narrow sense, to dissect the broad language faculty into sensorimotor, conceptual, and grammatical components, and to differentiate among the issues of shared versus unique abilities, gradual versus saltational evolution, and continuity versus change of evolutionary function. The rigorous laboratory study of possible homologues and analogues of aspects of language in other species is a hallmark of the research programs of Hauser and Fitch, and we agree that they promise major advances in our understanding of the evolution of language. Our disagreement specifically centers on the hypothesis that recursion is the only aspect of language that is special to it, that it evolved for functions other than language, and that this nullifies "the argument from design" that sees language as an adaptation.

The claims of HCF are carefully hedged, and the authors could argue that they are not actually advocating the recursion-only hypothesis but merely suggesting that it be entertained or speculating that it may turn out to be correct in the long run. We are not so much interested in pinning down who believes what as in accepting HCF's invitation to take the hypothesis itself seriously.

2. What's special: a brief examination of the evidence

We organize our discussion in line with HCF, distinguishing the conceptual, sensorimotor, and specifically linguistic aspects of the language faculty in turn.

2.1. Conceptual structure

Let us begin with the messages that language expresses: mental representations in the form of conceptual structure (or, as HCF put it, outputs of the "conceptual–intentional system"). The primate literature, incisively analyzed in HCF, gives us good reason to believe that some of the foundations of the human conceptual system are present in other primates, such as the major subsystems dealing with spatial, causal, and social reasoning. If chimpanzees could talk, they would have things to talk about that we would recognize.

HCF also argue that some aspects of the human conceptual system, such as Theory of Mind (intuitive psychology) and parts of intuitive physics, are absent in monkeys, and questionable or at best rudimentary in chimpanzees. They are special to humans, though not special to language. We add that many other conceptual systems, though not yet systematically studied in non-human primates, are conspicuous in human verbal interactions while being hard to discern in any aspect of primates' naturalistic behavior. They include essences (a major component of intuitive biology and chemistry), ownership, multi-part tools, fatherhood, romantic love, and most moral and deontic concepts. It is possible that these abilities, like Theory of Mind, are absent or discernable only in rudimentary form in other primates. These too would be uniquely human aspects of the language faculty in its broad sense, but would be part of a system for non-linguistic reasoning about the world rather than for language itself.

In addition, there are domains of human concepts which are probably unlearnable without language (Jackendoff, 1996). For example, the notion of a "week" depends on counting time periods that cannot all be perceived at once; we doubt that such a concept could be developed or learned without the mediation of language. More striking is the possibility that numbers themselves (beyond those that can be subitized) are parasitic on language—that they depend on learning the sequence of number words, the syntax of number phrases, or both (Bloom, 1994a; Wiese, 2004) (though see Grinstead, MacSwan, Curtiss, & Gelman, 1997, 2004, for a contrary view). Vast domains of human understanding, including the supernatural and sacred, the specifics of folk and formal science, human-specific kinship systems (such as the distinction between cross- and parallel cousins), and formal social roles (such as "justice of the peace" and "treasurer"), can be acquired only with the help of language.[4] The overall picture is that there is a substrate of conceptual structure in chimps, overlain by some uniquely human but not necessarily language-based subsystems, in turn overlain by subsystems that depend on the pre-existence of linguistic expression. So here we more or less concur with HCF, while recognizing a more ramified situation.

2.2. Speech perception

HCF implicitly reject Alvin Liberman's hypothesis that "Speech is Special" (SiS). According to SiS, speech recognition is a mode of perception that is distinct from our inherited primate auditory analyzers in being adapted to recover the articulatory intentions of a human speaker (Liberman, 1985, 1991; Liberman, Cooper, Shankweiler, & Studdert-Kennedy, 1967; Liberman & Mattingly, 1989). One of the first kinds of evidence adduced for SiS, dating to the 1950s, was the existence of categorical phoneme perception (Liberman et al., 1967), in which pairs of phonemes differing in say, voicing (e.g. *p* and *b*) are discriminated more accurately than pairs of stimuli separated by the same physical difference (in this case, in voice-onset time) but falling into the same phonemic category (both voiced, or both unvoiced). This particular bit of evidence for human uniqueness was deflated in the 1970s by findings that chinchillas make similar discriminations (Kuhl & Miller, 1975). HCF cite this as evidence against SiS, together with three other findings: that certain animals can make auditory distinctions based on formant frequency, that tamarin monkeys can learn to discriminate the gross rhythms of different languages, and that monkeys can perceive formants in their own species' vocalizations.

These phenomena suggest that at least some aspects of the ability to perceive speech were present long before the advent of language. Of course, some version of this conclusion is unavoidable: human ancestors began with a primate auditory system, adapted to perform complex analyses of the auditory world, and it is inconceivable that a system for speech perception in humans could have begun de novo. HCF go further and suggest that there have been *no* evolutionary changes to the mammalian auditory system

[4] We leave open whether such concepts are simply impossible without language or whether they are within the expressive power of the conceptual system but require language as a crutch to attain them. They certainly cannot be shared via ostension, so in either case language is necessary for their cultural transmission.

for the function of speech perception in humans. They suggest that this null hypothesis has withstood all attempts to reject it. We are not so sure.

Most experiments testing the perception of human speech by non-human animals have them discriminate pairs of speech sounds, often after extensive operant conditioning (supervised learning). It is not surprising that some animals can do so, or even that their perceptual boundaries resemble those of humans, since auditory analyzers suited for non-speech distinctions might suffice to discriminate among speech sounds, even if the analyzers humans use are different (Trout, 2001, 2003b). For example, a mammalian circuit that uses onset asynchrony to distinguish two overlapping auditory events from one event with a complex timbre might be sufficient to discriminate voiced from unvoiced consonants (Bregman & Pinker, 1978). But humans do not just make one-bit discriminations between pairs of phonemes. Rather, they can process a continuous, information-rich stream of speech. In doing so, they rapidly distinguish individual words from tens of thousands of distracters despite the absence of acoustic cues for phoneme and word boundaries, while compensating in real time for the distortions introduced by coarticulation and by variations in the age, sex, accent, identity, and emotional state of the speaker. And all of this is accomplished by children as a product of unsupervised learning. A monkey's ability to be trained to discriminate pairs of phonemes provides little evidence that its auditory system would be up to the task accomplished by humans. It would be extraordinarily difficult at present to conduct experiments that fairly compared a primate's ability to a human's, fully testing the null hypothesis.

Moreover, there is considerable evidence that *has* cast doubt on the null hypothesis (Anderson, 2004; Liberman, 1985, 1991; Remez, 1989, 1994; Trout, 2001, 2003b). First, speech and sound are phenomenologically different: under certain conditions, a given sound can be perceived simultaneously as part of a syllable and as a non-speechlike chirp (Liberman & Mattingly, 1989), or a stretch of sound can be heard to flip qualitatively between speech and non-speech (Remez, Pardo, Piorkowski, & Rubin, 2001).

Second, in humans the perception of speech dissociates in a number of ways from the perception of auditory events (the latter presumably using the analyzers we share with other primates). Neuroimaging and brain-damage studies suggest that partly distinct sets of brain areas subserve speech and non-speech sounds (Hickok & Poeppel, 2000; Poeppel, 2001; Trout, 2001; Vouloumanos, Kiehl, Werker, & Liddle, 2001). A clear example is pure word deafness, in which a neurological patient has lost the ability to analyze speech while recognizing other environmental sounds (Hickok & Poeppel, 2000; Poeppel, 2001). Cases of amusia and auditory agnosia, in which patients can understand speech yet fail to appreciate music or recognize environmental sounds (Peretz, Gagnon, & Bouchard, 1998; Poeppel, 2001), show that speech and non-speech perception in fact doubly dissociate.

Third, many of the complex hallmarks of speech perception appear early in infancy (Eimas & Miller, 1992; Miller & Eimas, 1983). Recent studies suggest that young infants, including neonates, prefer speech sounds to non-speech sounds with similar spectral and temporal properties. These include sounds that would have been indistinguishable in the womb, so the preference cannot be explained by learning in utero (Vouloumanos & Werker, 2004a,b). Moreover, neonates' sensitivity to speech appears to depend on the parts of the brain that subserve language in adults: a recent study using optical tomography showed that left-hemisphere temporal regions of the brains of newborns responded more to normal speech than to spectrally similar reversed speech (Peñaet al., 2003).

Fourth, comparisons among primates turn up significant differences between their abilities to perceive speech and our abilities. For example, monkeys fail to categorize consonants according to place of articulation using formant transitions alone (Sinnott & Williamson, 1999). They discriminate /ra/ from /la/ at a different boundary from the one salient to humans (Sinnott & Brown, 1997). They fail to segregate the initial consonant from the vowel when compensating for syllable length in discriminating phonemes (Sinnott, Brown, & Borneman, 1998). They fail to trade off the duration of the silent gap with the formant transition in perceiving stop consonants within consonant clusters (Sinnott & Saporita, 2000). They fail to show the asymmetrical "magnet effect" that characterizes infants' discrimination of speech sounds varying in acoustic similarity to prototype vowels (Kuhl, 1991). And their subjective similarity spaces among vowels (measured by discrimination reaction times analyzed by multidimensional scaling) is very different from that of humans (Sinnott, Brown, Malik, & Kressley, 1997). Chimpanzees, too, have a subjective similarity space for vowels that differs from humans', and, like macaques, have difficulty discriminating vowel pairs differing in advancement or frontness (Kojima & Kiritani, 1989). Quail (Trout, 2003a)[5] and budgerigars (Dooling & Brown, 1990) that have been trained to discriminate human speech sounds also show patterns of discrimination and generalization that differ from those of humans. A recent review of research on speech perception in humans, chinchillas, budgerigars, and quail showed that the phoneme boundaries for humans and animals differed in more than a third of the studies (Sinnott, 1998). These findings must be qualified by the fact that human speech perception necessarily reflects the effects of experience listening to a specific language, and it is difficult to equate such experience between humans and other animals. Nonetheless, if findings of similarities between humans and animals trained on human speech contrasts are taken as evidence that primate audition is a sufficient basis for human speech perception, findings of differences following such training must be taken as weakening such a conclusion.

2.3. Speech production

Turning to the articulatory side of speech, HCF cite two arguments against evolutionary adaptation for language in the human lineage. One is that some birds and primates produce formants (time-varying acoustic energy bands) in their vocalizations by manipulating the supralaryngeal vocal tract, a talent formerly thought to be uniquely human. Nonetheless, by all accounts such manipulations represent a minuscule fraction of the intricate gestures of lips, velum, larynx, and tip, body, and root of the tongue executed by speakers of all human languages (Browman & Goldstein, 1992; Hauser, 1996). Non-human primates are also notoriously resistant to training of their vocalizations (Hauser, 1996), and as HCF

[5] R. Remez, commenting in this reference on the work of Kluender (1994), notes that Kluender's trained quail failed to distinguish labial and palatal phonemes. He also suggests that the quail's ability to distinguish other place-of-articulation distinctions may hinge on their detecting the salient apical bursts that initiate stop consonants rather than the formant transitions that suffice for such discriminations in humans.

themselves note, they show no ability to learn vocalizations through imitation. HCF try to downplay the difference between humans and primates by pointing out that vocal imitation is not uniquely human. But this is irrelevant to the question of whether vocal imitation evolved for language in the human lineage. The other species that evolved comparable talents, namely certain birds and porpoises, are not ancestral to humans, and must have evolved their talents independently of what took place in human evolution.

Other evidence, not mentioned by HCF, also suggests that vocal production has been adapted for speech in humans. In comparison with extant apes and pre-*sapiens* hominids, modern humans have an enlarged region of the spinal cord responsible for the voluntary control over breathing required by speech production (MacLarnon & Hewitt, 1999).[6] Humans also display greater cortical control over articulation and breathing, compared with the largely subcortical control found in other primates (Deacon, 1997). And as Darwin noted, the innate vocal babbling of human infants is one of the clearest signs that "man has an instinctive tendency to speak."

To reconcile the recursion-only hypothesis with the fact that vocal learning and imitation are distinctively human (among primates), HCF refer to a "capacity for vocal imitation" and assign it to the "broad language faculty" which subsumes non-language-specific abilities. But this is questionable. Humans are not notably talented at vocal imitation in general, only at imitating speech sounds (and perhaps melodies). For example, most humans lack the ability (found in some birds) to convincingly reproduce environmental sounds. Even the ability to convincingly imitate a foreign or regional accent is the exception rather than the rule among human adults, and adults are notoriously poor at imitating the phonetics of a second language. Thus "capacity for vocal imitation" in humans might better be described as a capacity to learn to produce speech, contradicting the idea that grammatical recursion is the only human-specific and language-specific component of the language faculty.

HCF's second argument against human adaptations for speech production is the discovery that the descended human larynx (which allows a large space of discriminable vowels, while compromising other functions) can be found in certain other mammalian species, where it may have evolved to exaggerate perceived size. HCF note that while a descended larynx "undoubtedly plays an important role in speech production in modern humans, it need not have first evolved for this function" but may be an example of "preadaptation" (in which a trait originally was selected for a function other than the one it currently serves). But this suggestion, even if correct, does not speak to the issue of whether the human vocal tract was evolutionarily shaped to subserve human language. Modifications of function are ubiquitous in natural selection (for example, primate hands, bear paws, and bat wings are adaptations that evolved by natural selection from the fins of fish), so the fact that a trait was initially shaped by selection for one function does not imply that it was not subsequently shaped by selection for another function. Thus even if the larynx originally descended to exaggerate size, that says nothing about whether its

[6] The fact that *Homo erectus* had a spinal cord like that of other primates rules out an alternative hypothesis in which the change was an adaptation to bipedal locomotion.

current anatomical position was subsequently maintained, extended, or altered by selection pressures to enhance speech.

Moreover, evidence that the larynx was recently adapted for speech is stronger than evidence that it was originally adapted for size exaggeration. The human larynx is permanently descended in women, children, and infants past the age of 3 months (Lieberman, 1984), all of whom speak or are learning to speak, and none of whom, in comparison with adult males engaged in intrasexual competition, had much evolutionary incentive to exaggerate size if doing so would incur costs in other functions. Compare this with a related trait that is clearly adapted to size exaggeration in intrasexual competition, namely lowered vocal fundamental frequency. This trait, as expected, is specifically found in males of reproductive age. Moreover, even with its descended larynx, the human supralaryngeal vocal tract is no longer than what would be expected for a primate of our size, because the human oral cavity has shortened in evolution owing to the fact that humans, unlike chimpanzees, lack snouts (Lieberman, 2003). This further suggests that the vocal tract was not primarily shaped for size exaggeration. Finally, the descended larynx is part of a suite of vocal-tract modifications in human evolution, including changes in the shape of the tongue and jaw, that expand the space of discriminable speech sounds despite compromises in other organic functions, such as breathing, chewing, and swallowing (Lieberman, 1984, 2003). These other aspects of vocal tract anatomy are not addressed by HCF.

2.4. Phonology

Having the potential to articulate speech sounds—that is, having a vocal tract of the right shape and controllable in the right ways—is not the same as being able to produce the sounds of a language. The articulatory commands sent to the vocal tract to produce speech are organized in distinctive ways. Speech segments are drawn from a finite repertoire of phonemes, each defined by a set of discrete articulatory or acoustic feature values such as voicing, place of articulation, and mode of onset and release. Speech segments are concatenated into patterned rhythmic constituents such as syllables, feet, and prosodic phrases, upon which are superimposed systematic patterns of stress and pitch. The composition of the segments can then be modified in rule-governed ways according to their contexts (as in the three pronunciations of the past-tense suffix in *walked, jogged,* and *patted*). Languages differ in their repertoire of speech segments, their repertoire of syllable and intonation patterns, and in constraints, local and non-local, on how one sound can affect the pronunciation of others. This system of patterns and constraints is the subject matter of phonology.

The set of phonological structures of a language forms a "discrete infinity," a property which, in the case of syntax, HCF identify as one of the hallmarks of language. Just as every language has an unlimited number of syntactic structures built from a finite collection of morphemes, every language has an unlimited number of phonological structures, built from a finite repertoire of phonetic segments. One can always concatenate segments into longer and longer well-formed phonological sequences (whether meaningful or not). We note that the segmental and syllabic aspect of phonological structure, though discretely infinite and hierarchically structured, is not technically recursive.

Recursion consists of embedding a constituent in a constituent of the same type, for example a relative clause inside a relative clause (*a book that was written by the novelist you met last night*), which automatically confers the ability to do so ad libitum (e.g. *a book* [*that was written by the novelist* [*you met on the night* [*that we decided to buy the boat* [*that you liked so much*]]]]). This does not exist in phonological structure: a syllable, for instance, cannot be embedded in another syllable. Full syllables can only be concatenated, an operation that does not require a pointer stack or equivalent apparatus necessary to implement true recursion.[7]

Is phonological structure specific to language, or does it serve other more general purposes? Hierarchical and featural organization of gestures characterize other domains of motor control, such as manual manipulation. However, the kinds of constituents, the principles of combination, and the nature of the adjustment processes in phonology appear to be specific to language. And unlike motor programs, phonological structure is a level of representation that is crucially used both in perception and production.[8] Moreover, every language contains a set of partly arbitrary, learned conventions which permit certain kinds of articulatory shortcuts but prohibit others (that is why there are different accents), rather than being real-time adjustments to ease articulation or clarity.

Rhythmic organization similar to that of higher levels of phonological structure appears in music, but with somewhat different implementation. The two rhythmic components might be homologous the way fingers and toes are; hybrids of the two appear in poetry, song, and chant (Jackendoff, 1989; Lerdahl & Jackendoff, 1983). We do not know of other human capacities that have been shown to reflect this formal organization, though it is it an interesting open question.

Is phonology uniquely human? It appears that some of the combinatorial properties of phonology have analogues in some species of birdsong, and perhaps in some cetacean song, but not in any primates; if so, they would have to have evolved separately in humans. The rhythmic properties of language and music may well be unique to humans: informal observations suggest that no other primate can easily be trained to move to an auditory beat, as in marching, dancing, tapping the feet, or clapping the hands (Brown, Merker, & Wallin, 2000, p. 12). This is surely one of the most elementary characteristics of the human rhythmic response, and one that is displayed spontaneously by young children. And the rule-governed recombination of a repertoire of tones, which appears in music, tone languages, and more subtly in intonation contours of language, is as far as we know

[7] Syllables can sometimes be expanded by limited addition of non-syllabic material; the word *lengths*, for example, is in some theories analyzed as having syllabic structure along the line of $[_{Syl} [_{Syl}$ length] s] (Halle & Vergnaud, 1980). But there are no syllables built out of the combination of two or more full syllables, which is the crucial case for true recursion.

[8] The existence in monkeys of mirror-neurons (Rizolatti, Fadiga, Gallese, & Fogassi, 1996), which are active both in the execution and the sight of particular actions, suggests that some kind of representation shared by perception and production antedates the evolution of language in humans. However, the information coded by such neurons appears to be different from phonological representations in two ways. First, they are specific to the semantic goal of an action (e.g. obtaining an object), rather than its physical topography, whereas phonology is concerned with configurations for articulation. Second, as noted by HCF, they do not support transfer from perception to production, since the ability to imitate is rudimentary or absent in monkeys, whereas humans learn to articulate speech sounds based on what they hear.

unparalleled elsewhere. So overall, major characteristics of phonology are specific to language (or to language and music), uniquely human, discretely infinite, and not recursive. Thus phonology represents a major counterexample to the recursion-only hypothesis.

We note that there are good adaptive reasons for a distinct level of combinatorial phonological structure to have evolved as part of the language faculty. As noted as early as Hockett (1960), "duality of patterning"—the existence of two levels of rule-governed combinatorial structure, one combining meaningless sounds into morphemes, the other combining meaningful morphemes into words and phrases—is a universal design feature of human language. A combinatorial sound system is a solution to the problem of encoding a large number of concepts (tens of thousands) into a far smaller number of discriminable speech sounds (dozens). A fixed inventory of sounds, when combined into strings, can multiply out to encode a large number of words, without requiring listeners to make finer and finer analogue discriminations among physically similar sounds. Recently Nowak and his collaborators have borne out this speculation in computer simulations of language evolution (Nowak & Krakauer, 1999).

Phonological adjustment rules also have an intelligible rationale. Phonologists have long noted that many of them act to smooth out articulation or enhance discriminability. Since these two requirements are often at cross-purposes (slurred speech is easy to produce but hard to discriminate; exaggerated enunciation vice-versa), a fixed set of rules delineating which adjustments are mandated within a speech community may act in service of the "parity" requirement of language (Liberman & Mattingly, 1989; Slobin, 1977), namely that the code be usable both by speakers and hearers.

Whether or not these hypotheses about the adaptive function of phonology are correct, it is undeniable that phonology constitutes a distinct level of organization of all human languages. Surprisingly, HCF make no mention of phonology, only of perception and articulation.

2.5. Words

We now come to an aspect of language that is utterly essential to it: the word. In the minimal case, a word is an arbitrary association of a chunk of phonology and a chunk of conceptual structure, stored in speakers' long-term memory (the lexicon). Some words, such as *hello*, *ouch*, *yes*, and *allakazam*, do not combine with other words (other than trivially, as in direct quotes). But most words (as well as smaller morphemes such as affixes) can combine into complex words such as compounds (e.g. *armchair*) and other derived forms (e.g. *squeezability*) according to principles of the component of language called morphology. Morphology, together with syntax, constitutes the classical domain of recursion à la HCF.

As acknowledged by HCF in passing, words have several properties that appear to be uniquely human. The first is that there are so many of them—50,000 in a garden-variety speaker's lexicon, more than 100 times the most extravagant claims for vocabulary in language-trained apes or in natural primate call systems (Wallman, 1992). The second is the range and precision of concepts that words express, from concrete to abstract (*lily, joist, telephone, bargain, glacial, abstract, from, any*). Third, they all have to be learned.

This certainly requires proficiency at vocal imitation, as HCF note. But it also requires a prodigious ability to construct the proper meaning on the basis of linguistic and non-linguistic context. Children come into their second year of life expecting the noises other people make to be used symbolically; much of the job of learning language is figuring out what concepts (or sets of things in the world, depending on your view of semantics) these noises are symbols for.

HCF observe that "the rate at which children build the lexicon is so massively different from non-human primates that one must entertain the possibility of an independently evolved mechanism." They also observe that "unlike the best animal examples of putatively referential signals, most of the words of human language are not associated with specific functions" (1576) and may be "detached from the here and now," another feature of words that may be "uniquely human." These suggestions, however, contradict their claim that the narrow language faculty "only includes recursion and is the only uniquely human component of the faculty of language." They reconcile the contradiction by retaining the idea that the narrow language faculty includes only recursion but weakening the idea that only the narrow language faculty is uniquely human; specifically, they relegate word leaning to the broad language faculty. They do so by suggesting that word learning is not specific to language, citing the hypothesis, which they attribute to Bloom (1999) and Markson and Bloom (1997) that "human children may use domain-general mechanisms to acquire and recall words." Actually, while Markson and Bloom did argue against a dedicated system for learning words, they did not conclude that words are acquired by a *domain-general* mechanism. Rather, they argued that word-learning is accomplished by the child's Theory of Mind, a mechanism specific to the domain of intuitive psychology, possibly unique to humans.

In any case, the conclusion that there are no mechanisms of learning or representation specific to words may be premature. The experiment by Markson and Bloom cited by HCF showed that children display similar levels of recognition memory after a single exposure to either a new word or a new fact (e.g. "My uncle gave it to me"). But on any reasonable account, words and facts are stored using the same kinds of neural mechanisms responsible for storage, retention, and forgetting. A demonstration that word learning and fact learning have this property in common does not prove they have all their properties in common.

Markson and Bloom's case that word learning can be reduced to a Theory of Mind mechanism is most tenable for the basic act of learning that a noun is the label for a perceptible object. But words are not just names for things (see Bloom, 1999). They also are marked for a syntactic category (verb, preposition, and so on), for obligatory grammatically encoded arguments (agent, theme, path, and so on), and for selection restrictions on the syntactic properties of their complements (e.g. whether each one is headed by a preposition, a finite verb, or a non-finite verb). This information, which is partly idiosyncratic to each word and therefore must be stored in the lexicon, critically governs how the word enters into the recursive components of grammar (morphology and syntax); it cannot be identified with the conceptual database that makes up general world knowledge.

Moreover, functional morphemes such as articles, auxiliaries, and affixes are also part of the lexicon (since each involves a pairing between a sound and some other information, both of which are specific to the particular language), yet the information they encode (case, agreement, finiteness, voice, and so on) is continuous with the information encoded by syntax. Such words are not used, and presumably could not be acquired, in isolation from some syntactic context. And as functional morphemes go, so go verbs, since verbs encode similar kinds of grammatical and semantic information (Gentner, 1981; Pinker, 1989; Talmy, 1985), have similarly close linguistic, psychological, and neurological ties to syntax (Gentner, 1981; Pinker, 1989; Shapiro, Pascual-Leone, Mottaghy, Gangitano, & Caramazza, 2001), and, at least in part, require syntactic analysis to be acquired (Gleitman, 1990; Pinker, 1994a). So other than acquiring the names for salient things, it is hard to see how words can be carved away from the narrow language faculty and relegated to a generic mechanism that learns facts from people's intentions.

Even in the case of learning nouns, there are reasons to suspect that children treat facts and words in different ways. These different ways reflect the hallmarks of words that distinguish them from other kinds of factual knowledge. One is that words are bidirectional and arbitrary ("Saussurean") signs: a child, upon hearing a word used by a speaker, can conclude that other speakers in the community, and the child himself or herself, may use the word with the same meaning and expect to be understood (Hurford, 1989). This is one of the assumptions that allows babies to use words upon exposure to them, as opposed to needing to have their vocal output shaped or reinforced by parental feedback. Diesendruck and Markson (2001) (see also Au & Glusman, 1990) showed that young children tacitly assume that speakers share a code. If one speaker labels a novel object as a *mep* out of earshot of a second speaker, and the second speaker then asks about a *jop*, the children interpret the second speaker as referring to a different object. Presumably it is because they attributed common knowledge of a name (*mep*) to that speaker, even though they had never witnessed that speaker learning the name. In contrast, if one speaker mentions a *fact* about an object (e.g. "my sister gave it to me") out of earshot of a second speaker, and the second speaker then asks about an object characterized by another fact (e.g. "dogs like to play with it"), they do not interpret the second speaker as referring to a different object. Presumably this is because they do not attribute common knowledge of facts to the members of a speech community the way they do with words. Somewhat to their surprise, Diesendruck and Markson conclude, "Interestingly, the present findings lend indirect support to the idea that in some respects, word learning *is* special" (p. 639).

Another hallmark of words is that their meanings are defined not just by the relation of the word to a concept but by the relation of the word to other words in the lexicon, forming organized sets such as superordinates, antonyms, meronyms (parts), and avoiding true synonyms (Clark, 1993; Deacon, 1997; Miller, 1991; Miller & Fellbaum, 1991). Behrend and collaborators (Behrend, Scofield, & Kleinknecht, 2001; Scofield & Behrend, 2003), refining a phenomenon discovered by Markman (1989), showed that two-year-old children assign a novel word to an object they are unfamiliar with rather than to one they are familiar with (presumably a consequence of an avoidance of synonymy), but they show no such effect for novel facts.

Another distinctive feature about words is that (with the exception of proper names, which in many regards are more like phrases than words; (see Bloom, 1994b) they are generic, referring to kinds of objects and events rather than specific objects and events (di Sciullo & Williams, 1987). Waxman and Booth (2001), and Behrend et al. (2001) showed that children generalize a newly learned noun to other objects of the same kind, but do not generalize a newly learned fact (e.g. "my uncle gave it to me") to other objects of the same kind. Similarly, Gelman and Heyman (1999) showed that children assume that a person labeled with the word *carrot-eater* has a taste for carrots, whereas one described as eating carrots (a fact about the person) merely ate them at least once.

Our assessment of the situation is that words, as shared, organized linkages of phonological, conceptual, and grammatical structures, are a distinctive language-specific part of human knowledge. The child appears to come to social situations anticipating that the noises made by other humans are made up of words, and this makes the learning of words different in several regards from the learning of facts. Moreover, a good portion of people's knowledge of words (especially verbs and functional morphemes) consists of exactly the kind of information that is manipulated by recursive syntax, the component held to make up the narrow language faculty. This makes it difficult to hold that the capacity to represent and learn words is part of a general knowledge system that evolved independently of the demands of language.

2.6. Syntax

We finally turn to syntactic structure, the principles by which words and morphemes are concatenated into sentences. In our view, syntax functions in the overall system of language as a regulator: it helps determine how the meanings of words are combined into the meanings of phrases and sentences. Every linguist recognizes that (on the surface, at least), syntax employs at least four combinatorial devices. The first collects words hierarchically into syntactic phrases, where syntactic phrases correspond (in prototypical cases) to constituents of meaning. (For example, word strings such as *Dr Ruth discussed sex with Dick Cavett* are ambiguous because their words can be grouped into phrases in two different ways). This is the recursive component referred to by HCF. The second orders words or phrases within a phrase, for example, by specifying that the verb of a sentence falls in a certain position such as second, or that the phrase serving as the topic comes first. Most languages of the world are not as strict about word order as English, and often the operative principles of phrase order concern topic and focus, a fairly marginal issue in English grammar. A third major syntactic device is agreement, whereby verbs or adjectives are marked with inflections that correspond to the number, person, grammatical gender, or other classificatory features of syntactically related nouns. The fourth is case-marking, whereby noun phrases are marked with inflections (nominative, accusative, and so on) depending on the grammatical role of the phrase with respect to a verb, preposition, or another noun.

Different languages rely on these mechanisms to different extents to convey who did what to whom, what is where, and other semantic relations. English relies heavily on order and constituency, but has vestigial agreement and no case except on pronouns. The Australian language Warlpiri has virtually free word order and an exuberant system of case and agreement; Russian and Classical Latin are not far behind. Many languages use the systems redundantly, for instance German, with its rich gender and case systems, moderate use of agreement, and fairly strong constraints on phrase order.

And this barely scratches the surface. Languages are full of devices like pronouns and articles, which help signal which information the speaker expects to be old or new to the hearer; quantifiers, tense and aspect markers, complementizers, and auxiliaries, which express temporal and logical relations; restrictive and appositive modification (as in relative clauses); and grammatical distinctions among questions, imperatives, statements, and other kinds of illocutionary force, signaled by phrase order, morphology, or intonation. A final important device is long-distance dependency, which can relate a question word or relative pronoun to a distant verb, as in *Which theory did you expect Fred to think Melvin had disproven last week?*, where *which theory* is understood as the object of *disprove*.

Is all this specific to language? It seems likely, given that it is specialized machinery for regulating the relation of sound and meaning. What other human or non-human ability could it serve? Yet aside from phrase structure (in which a noun phrase, for example, can contain a noun phrase, or a sentence can contain a sentence) and perhaps long-distance dependencies,[9] none of it involves recursion per se. A case marker may not contain another instance of a case marker; an article may not contain an article; a pronoun may not contain a pronoun, and so on for auxiliaries, tense features, and so on. HCF cite none of these devices as part of language, although each weakens the hypothesis that the narrow language faculty consists only of recursion.

Indeed, at least one language seems to rely entirely on these devices, forgoing use of the recursive power of syntax entirely. Based on 30 years of fieldwork on the Amazonian language Pirahã, Everett (2004) claims that this language lacks any evidence of recursion. All semantic relations conveyed by clausal or NP embedding in more familiar languages, such as conditionality, intention, relative clauses, reports of speech and mental states, and recursive possession (*my father's brother's uncle*), are conveyed in Pirahã by means of monoclausal constructions connected paratactically (i.e. without embedding). However, Pirahã very clearly has phonology, morphology, syntax, and sentences, and is undoubtedly a human language, qualitatively different from anything found in animals.

HCF do discuss the ability to learn linearly ordered recursive phrase structure. In a clever experiment, Fitch and Hauser (2004) showed that unlike humans, tamarins cannot learn the simple recursive language A^nB^n (all sequences consisting of n instances of the symbol A followed by n instances of the symbol B; such a language can be generated by the recursive rule $S \rightarrow A(S)B$). But the relevance of this result to HCF's argument is unclear. Although human languages are recursive, and A^nB^n is recursive, A^nB^n is not a possible human language. No natural language construction has such phrases, which violate the X-bar principles that have long been at the heart of the mainstream theory of Universal Grammar (Chomsky, 1972).[10] If the conclusion is that human syntactic competence consists only of an ability to learn recursive languages

[9] Long-distance dependency can involve dependencies extending into recursively embedded structures, and on some accounts involves recursive movement of the fronted phrase up through the phrase structure tree.

[10] Also unclear is whether the human subjects who learned these artificial languages did so by using the strong generative capacity of an A^nB^n grammar. Each stimulus consisted of a sequence of nonsense syllables spoken by a female voice followed by an equal number of syllables spoken by a male voice. Phonological content was irrelevant, and the learning could have been accomplished by counting from the first syllable of each subsequence (*high:1–2–3; low:1–2–3*). This differs from the kind of analysis mandated by a grammar of recursively embedded phrases, namely [*high*–[*high*–[*high*–*low*]–*low*]–*low*].

(which embrace all kinds of formal systems, including computer programming languages, mathematical notation, the set of all palindromes, and an infinity of others), the fact that actual human languages are a minuscule and well-defined subset of recursive languages is unexplained.

2.7. Summary of evidence on the recursion-only hypothesis

The state of the evidence for HCF's hypothesis that only recursion is special to language is as follows:

- Conceptual structure: HCF plausibly suggest that human conceptual structure partly overlaps with that of other primates and partly incorporates newly evolved capacities.
- Speech perception. HCF suggest it is simply generic primate auditory perception. But the tasks given to monkeys are not comparable to the feats of human speech perception, and most of Liberman's evidence for the Speech-is-Special hypothesis, and more recent experimental demonstrations of human–monkey differences in speech perception, are not discussed.
- Speech production. HCF's recursion-only hypothesis implies no selection for speech production in the human lineage. But control of the supralaryngeal vocal tract is incomparably more complex in human language than in other primate vocalizations. Vocal imitation and vocal learning are uniquely human among primates (talents that are consistently manifested only in speech). And syllabic babbling emerges spontaneously in human infants. HCF further suggest that the distinctively human anatomy of the vocal tract may have been selected for size exaggeration rather than speech. Yet the evidence for the former in humans is weak, and does not account for the distinctive anatomy of the supralaryngeal parts of the vocal tract.
- Phonology. Not discussed by HCF.
- Lexicon. HCF discuss two ways in which words are a distinctively human ability, possibly unique to our species. But they assign words to the broad language faculty, which is shared by other human cognitive faculties, without discussing the ways in which words appear to be tailored to language—namely that they consist in part (sometimes in large part) of grammatical information, and that they are bidirectional, shared, organized, and generic in reference, features that are experimentally demonstrable in young children's learning of words.
- Morphology: Not discussed by HCF.
- Syntax: Case, agreement, pronouns, predicate-argument structure, topic, focus, auxiliaries, question markers, and so on, are not discussed by HCF. Recursion is said to be human-specific, but no distinction is made between arbitrary recursive mathematical systems and the particular kinds of recursive phrase structure found in human languages.

We conclude that the empirical case for the recursion-only hypothesis is extremely weak.

2.8. Some genetic evidence

Recent findings from genetics cast even stronger doubt on the recursion-only hypothesis. There is a rare inherited impairment of language and speech caused by a dominant allele of a single gene, FOXP2 (Lai, Fisher, Hurst, Vargha-Khadem, & Monaco, 2001). The gene has been sequenced and subjected to comparative analyses, which show that the normal version of the gene is universal in the human population, that it diverged from the primate homologue subsequent to the evolutionary split between humans and chimpanzees, and that it was a target of natural selection rather than a product of genetic drift or other stochastic evolutionary processes (Enard et al., 2002). The phenotype is complex and not completely characterized, but it is generally agreed that sufferers have deficits in articulation, production, comprehension, and judgments in a variety of domains of grammar, together with difficulties in producing sequences of orofacial movements (Bishop, 2002; Gopnik & Crago, 1991; Ullman & Gopnik, 1999; Vargha-Khadem, Watkins, Alcock, Fletcher, & Passingham, 1995). The possibility that the affected people are impaired only in recursion is a non-starter. These findings refute the hypothesis that the only evolutionary change for language in the human lineage was one that grafted syntactic recursion onto unchanged primate input–output abilities and enhanced learning of facts. Instead they support the notion that language evolved piecemeal in the human lineage under the influence of natural selection, with the selected genes having pleiotropic effects that incrementally improved multiple components.

FOXP2, moreover, is just the most precisely identified of a number of genetic loci that cause impairments of language, or related impairments such as stuttering and dyslexia (Dale et al., 1998; Stromswold, 2001; The SLI Consortium, 2002; van der Lely, Rosen, & McClelland, 1998). None of these impairments knock out or compromise recursion alone. Even in the realm of speech perception, genetic evidence may point to adaptation for language. A recent comparison of the genomes of mice, chimpanzees, and humans turned up a number of genes that are expressed in the development of the auditory system and that have undergone positive selection in the human lineage (Clark et al., 2003). Since speech is the main feature that differentiates the natural auditory environments of humans and of chimpanzees, the authors speculate that these evolutionary changes were in the service of enhanced perception of speech.

As more genes with effects on speech and language are identified, sequenced, and compared across individuals and species, additional tests contrasting the language-as-adaptation hypothesis with the recursion-only hypothesis will be available. The latter predicts heritable impairments that completely or partially knock out recursion but leave people with abilities in speech perception and speech production comparable to those of chimpanzees. Our reading of the literature on language impairment is that this prediction is unlikely to be true.

3. The minimalist program as a rationale for the recursion-only hypothesis

Given the disparity between the recursion-only hypothesis and the facts of language, together with its disparity from Chomsky's earlier commitment to complexity and modularity, one might wonder what motivated the hypothesis. We believe that it arises from Chomsky's current overall approach to the language faculty, the Minimalist Program (MP) (Chomsky, 1995, 2000a,b; Lasnik, 2002). This is a decade-long attempt at a unified theory for language, based on the following vision. Since language is a mapping between sounds and meanings, only representations of sound (Phonetic Form) and representations of meaning (Logical Form) are truly indispensable. Other than these representations, whose existence is, in Chomsky's terminology, a "virtual conceptual necessity," all other linguistic structures and the principles applying to them, being conceptually unnecessary, should be eliminated. These include the long-prominent deep structure (or d-structure) and surface structure (s-structure). The minutiae of linguistic phenomena should instead be explained by details of words (which uncontroversially are specific to a particular language and must be learned) and certain principles of "economy" that apply to the mapping between meaning and sound. In this way, the core of language may be characterized as an optimal or "perfect system," containing only what is conceptually necessary. The messy complexity of linguistic phenomena comes from the need to interface with the systems for sounds and concepts, which necessarily embody the complexity of human thoughts and speech organs.

Since language combines words into hierarchical tree structures, it is necessary for the language faculty to include, at a minimum, an operation for combining items. In the Minimalist Program this mechanism, called *Merge*, recursively joins two elements (words or phrases) into a binary tree bearing the label of one of them. The Minimalist commitment to bare necessity leads to the conjecture that Merge is the *only* element necessary to create the system of language. The vast number of logical possibilities for constructing erroneous derivations using Merge are kept in check by several principles of economy, which dictate, for example, that certain operations are to be executed later rather than earlier in a derivation, that local relations among elements are to be preferred to longer-distance ones, or that simple operations are to be preferred to more complex ones.

The Minimalist Program appears to be parsimonious and elegant, eschewing the baroque mechanisms and principles that emerged in previous incarnations of generative grammar such as the Extended Standard Theory and Government-Binding Theory (Chomsky, 1972, 1981). And the implications for the evolution of language are clear. If language per se does not consist of very much, then not much had to evolve for us to get it: Merge would be the only thing that had to be added to the pre-existing auditory, vocal, and conceptual systems. This modification even have been effected by a single genetic change that became fixed in the population through drift or other random processes. Therefore invoking natural selection to explain the adaptive complexity of language (analogously to the way it is invoked to explain the adaptive complexity of the vertebrate eye or echolocation in bats) is no longer necessary (Boeckx & Piatelli-Palmarini, in press; Hornstein, 2002; Piatelli-Palmarini & Uriagereka, in press). Indeed, HCF themselves point out the connection between the recursion-only hypothesis and the Minimalist Program:

> Recent work on FLN suggests the possibility that at least the narrow-syntactic component satisfies conditions of highly efficient computation to an extent previously unsuspected.… [T]he generative processes of the language system may provide a near-optimal solution that satisfies the interface conditions to FLB.

> Many of the details of language that are the traditional focus of linguistic study … may represent by-products of this solution, generated automatically by neural/computational constraints and the structure of FLB-components that lie outside of FLN.

The major difficulty with the Minimalist Program, as Chomsky (2000b, p. 124) himself admits, is that "All the phenomena of language appear to refute it." He reassures the reader immediately by adding, "… just as the phenomena of the world appeared to refute the Copernican thesis. The question is whether this is a real refutation." There follows an extended discussion of how science is always deciding which evidence is relevant and which to discard. The general point is unexceptionable, but it offers few grounds for confidence that the *particular* theory under discussion is correct. After all, any theory can be rescued from falsification if one chooses to ignore enough inconvenient phenomena (see also Newmeyer, 2003). The Minimalist Program, in Chomsky's original conception, chooses to ignore:

- all the phenomena of phonology.
- most or all the phenomena of derivational morphology, such as compounds and complex inflected forms.[11]
- most of the phenomena of inflectional morphology: the leading theory in the Chomskyan framework, Halle and Marantz's Distributive Morphology, does not naturally conform to the principles of Minimalism (Halle & Marantz, 1993), and considerable work must be done to reconcile them.
- many basic phrase structures, such as those involved in modification.[12]
- many phenomena of phrase and word order, such as topic and focus, figure and ground, and effects of adjacency and linearity.[13] There is also no account of free word order phenomena, characteristic of many languages of the world.
- the source and nature of lexical entries, which do considerable work in the theory (defining phrase structures, triggering movement), and which therefore are far more abstract and language-specific than mere sound-meaning pairings.
- the connection of the grammar to processing (a difficulty shared with previous versions of Chomskyan theory).
- the connection of the grammar to acquisition, especially how the child can identify the numerous abstract features and configurations that are specific to languages but have no perceptible correlate (see Culicover, 1999; Pinker, 1984, 1987).

In fact, most of the technical accomplishments of the preceding 25 years of research in the Chomskyan paradigm must be torn down, and proposals from long-abandoned

[11] "I have said nothing about other major components of the theory of word formation: compound forms, agglutinative structures, and much more" (Chomsky, 1995, p. 241).

[12] "We still have no good phrase structure theory for such simple matters as attributive adjectives, relative clauses, and adjuncts of many different types" (Chomsky, 1995, p. 382, n. 22).

[13] "I am sweeping under the rug questions of considerable significance, notably, questions about what in the earlier framework were called "surface effects" on interpretation. These are manifold, including topic-focus and theme-rheme structures, figure-ground properties, effects of adjacency and linearity, and many others" (Chomsky, 1995, p. 220).

1950s-era formulations and from long-criticized 1970s-era rivals must be rehabilitated (Pullum, 1996).[14]

We do not disagree with Chomsky that a new theory should be cut some slack if it promises advances in parsimony or explanatory power. But in practice, the elegance, economy, and conceptual necessity claimed for Minimalism turn out not to be so obvious. For instance, when Chomsky says that Minimalism does without deep and surface structures, he means only that these structures are not singled out as representations to which constraints such as the Projection Principle or Case Filter apply. The theory still posits that the derivation of every sentence involves a sequence of abstract syntactic trees, related by movement operations or their equivalent. These trees, moreover, are anything but minimal. They contain full branching structures for just about every morpheme (including articles and complementizers), for inflectional features like "tense" and "agreement", and for numerous empty nodes which morphemes are destined to move to or be coindexed with. For example, in the version of Chomsky (1995), a sentence like *John saw Mary* has a tree with six levels of embedding, four traces (the result of four movement operations), and five alternative derivations that need to be compared to ensure that one of the economy requirements has been satisfied (Johnson & Lappin, 1997). Moreover, the lexicon is not just a conceptually necessary list of sound-meaning pairings for identifiable words: it is packed with abstract morphemes and features (such as the "strength" of agreement) whose main rationale is to trigger the right syntactic phenomena, thereby offloading work from the syntactic component and preserving its "minimalist" nature.

Just as Minimalist syntax is far from minimalist, the "principles of economy" that regulate these derivations are not particularly economical. As noted by several critics (Johnson & Lappin, 1997, 1999; Lappin, Levine, & Johnson, 2000; Newmeyer, 2003; Pullum, 1996), these are not independently motivated by least-action principles of physics, resource limitations in cognitive information processing, or mechanical symbol- or step-counting in some formal notation (any of which might, in some sense, come "for free"). Rather, they are a mixture of metaphors involving speed, ease, cost, and need, and anthropomorphic traits such as "greed", "procrastination", and "last resort." Insofar as their desired effects on linguistic structures are clear at all, those effects must be explicitly stipulated, and would have to be spelled out as complicated conditions on operations in any explicit implementation. (That is, they are not derivable mathematically from deeper principles in the way that principles of naïve physics like "water finds its own level" are derivable from principles of energy minimization). Moreover, implementing the conditions requires the processor to choose an optimal derivation from among a set of possibilities, a requirement which is computationally far more complex than the implementations of other extant theories of grammar, where conditions may be checked locally against information available at each step within a single derivation (Johnson & Lappin, 1997, 1999).[15]

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[14] "The minimalist program seeks to show that everything that has been accounted for in terms of [deep and surface structure] has been misdescribed … that means the projection principle, binding theory, Case theory, the chain condition, and so on" (Chomsky, 2000a, p. 10).

[15] Johnson and Lappin (1999) show that the "principles of economy" are problematic not just in Chomsky's original formulation in which entire derivations are compared, but for subsequent proposals based on "local economy" in which principles are evaluated at individual steps in a derivation.

To be fair, recent work on Minimalism has tried to fill in the gaps and address the problems of Chomsky's original formulations. Yet it is just as clear that such work should not be taken as empirically vindicating Minimalist hypotheses about the empirical nature of language, but rather as carrying out a mandate to implement this vision of Chomsky's. We share the bemusement of Lappin et al. (2000) who write, "What is altogether mysterious from a purely scientific point of view is the rapidity with which a substantial number of investigators, who had significant research commitments in the Government-Binding framework, have abandoned that framework and much of its conceptual inventory, virtually overnight. In its place they have adopted an approach which, as far as we can tell, is in no way superior with respect to either predictive capabilities or explanatory power" (p. 667). Most of the work has consisted of reformulations to meet theory-internal desiderata rather than empirical tests of competing hypotheses, and such simplifications as have been achieved have been at the expense of relegating an increasing number of phenomena to unknown "interface phenomena." The numerous critical analyses of Minimalism which have appeared in the literature (Johnson & Lappin, 1997, 1999; Lappin et al., 2000; Newmeyer, 2003; Postal, 2004; Pullum, 1996; Rochemont & Culicover, 1997; Seuren, 2004) differ considerably in politeness but are remarkably similar in substance.

The conjectural status of Minimalism has been emphasized not just by critics but by the practitioners themselves. Koopman (2000, p. 2), has written that Minimalism "led to relatively few new insights in our understanding of phenomena in the first half of the nineties. This is probably because it did not generate new analytical tools, and thus failed to generate novel ways of looking at well-known paradigms or expand and solve old problems, an essential ingredient for progress to be made at this point" (p. 2). Lasnik's recent tutorial (Lasnik, 2002) concedes that after more than a dozen years, "Minimalism is as yet still just an 'approach', a conjecture about how language works ('perfectly') and a general program for exploring and developing the conjecture" (p. 436). An enthusiastic exposition by Boeckx and Hornstein (in press) includes a caveat (attributed to Chomsky) that "The only note of caution worth bearing in mind is that the Minimalist Program may be premature" (p. 18).

We conclude that on both empirical and theoretical grounds, the Minimalist Program is a very long shot. This is not to say that we believe all of generative grammar should be abandoned. Indeed, we have both written passionate expositions of the overall program, defending core assumptions such as that language is a combinatorial, productive, and partly innate mental system (Jackendoff, 1994, 2002; Pinker, 1994b). But it is necessary to evaluate what aspects of the current mainstream version of generative grammar to keep and what to replace (see (Culicover & Jackendoff, in press; Jackendoff, 2002), for assessments).

Returning to our main question of what is special about language: Behind HCF's claim that the only aspect of language that is special is recursion lies a presumption that the Minimalist Program is ultimately going to be vindicated. The linguistic phenomena they ignore, listed in Section 2, are among the phenomena also set aside in the overall vision of the MP, listed in this section. Given the empirical status of MP, it seems shaky at best to presume it or its variants when drawing conclusions about the evolution of language.

4. Language, communication, and evolution

The intuition that Minimalism reduces the amount of linguistic machinery that had to evolve is not HCF's only argument against the possibility that natural selection was a crucial cause of the evolution of the language faculty. They touch on three other themes that comprise an overall vision of what language is like. These are:

- Language is not "for" communication and may even be badly designed for communication (thus "nullifying the argument from design").
- Language is an "optimal" or "perfect" mapping between sound and meaning, and in this perfection it is unlike other biological systems.
- The narrow language faculty was not selected for language but originated in some other cognitive ability.

These hypotheses challenge a more conventional evolutionary vision of language, according to which the language faculty evolved gradually in response to the adaptive value of more precise and efficient communication in a knowledge-using, socially interdependent lifestyle (Nowak & Komarova, 2001; Nowak & Krakauer, 1999; Nowak, Plotkin, & Jansen, 2000; Pinker, 1994b, 2003; Pinker & Bloom, 1990; Tooby & DeVore, 1987). Gradual emergence implies that later stages had to build on earlier ones in the contingent fashion characteristic of natural selection, resulting in a system that is better than what existed before but not necessarily optimal on first principles (Bickerton, 1990; Givon, 1995; Jackendoff, 2002). We consider these assertions in turn.

4.1. Language is badly designed for communication

The operative quote from HCF is this:

> The question is whether particular components of the functioning of FLN are adaptations for language, specifically acted upon by natural selection—or, even more broadly, whether FLN evolved for reasons other than communication (1574).

This passage is an allusion to a position that Chomsky has developed at greater length in other writings:

> … language is not properly regarded as a system of communication. It is a system for expressing thought, something quite different. It can of course be used for communication, as can anything people do—manner of walking or style of clothes or hair, for example. But in any useful sense of the term, communication is not the function of language, and may even be of no unique significance for understanding the functions and nature of language (Chomsky, 2000b, p. 75).
>
> Language design as such appears to be in many respects "dysfunctional," yielding properties that are not well adapted to the function language is called upon to perform. … What we seem to discover are some intriguing and unexpected features of language design … [which are] unusual among biological systems of the natural world (Chomsky, 1995, p. 162).

These claims are, to say the least, surprising. At least since the story of the Tower of Babel, everyone who has reflected on language has noted its vast communicative power and indispensable role in human life. Humans can use language to convey everything from gossip, recipes, hunting techniques, and reciprocal promises to theories of the origin of the universe and the immortality of the soul. This enormous expressive power clearly meshes with two of the other zoologically unusual features of *Homo sapiens*: a reliance on acquired know-how and a high degree of cooperation among non-kin (Pinker, 1997; Tooby & DeVore, 1987). Moreover the design of language—a mapping between meaning and sound—is precisely what one would expect in a system that evolved for the communication of propositions. We cannot convey recipes, hunting techniques, gossip, or reciprocal promises by "manner of walking or style of clothes or hair," because these forms of behavior lack grammatical devices that allow propositions to be encoded in a recoverable way in details of the behavior. Though Chomsky denies the truism that language is "properly regarded as a system for communication," he provides no compelling reasons to doubt it, nor does he explain what a communication system would have to look like for it to be more "usable" or less "dysfunctional" than human languages.

Chomsky's positive argument that language is not "for" communication is that "language use is largely to oneself: 'inner speech' for adults, monologue for children" (Chomsky, 2000b, p. 77). HCF make the point indirectly in the passage quoted above. In part, they are distancing oneself from claims that language is a homologue of primate calls, a point with which we agree. But in order to make this point, one need not deny that language is for communication, or claim that it could just as easily be thought of as being for inner speech.

For one thing, the fragmentary snatches of inner speech that run through a person's mind are likely to be quite different from the well-formed sentences that motivate Chomsky's theories of linguistic competence. Other than in preparation for speaking and writing, interior monologues do not seem to consist of fully grammatical sequences of words complete with functional morphemes, such as *The teachers asked what attitudes about each other the students had noticed*, but rather of snatches of incomplete phrases. Whatever mechanism underlies inner speech—presumably the phonological loop that makes up a major component of working memory—it is not subject matter of any familiar theory of grammatical competence.

Moreover, the key question in characterizing a biological function is not what a trait is typically *used* for but what it is *designed* for, in the biologist's sense—namely, which putative function can predict the features that the trait possesses. For all we know, hands might be used more often in fidgeting than grasping, but that would not make fidgeting the biological function of the hand. The reason is that hands have improbable anatomical features that are necessary for grasping but not for fidgeting. By similar logic, a system for "talking to oneself" would not need phonology or phonetics tuned to the properties of the human vocal tract, it would not need linear order or case or agreement, and it would not need mechanisms for topic and focus, all of which presuppose that information has to be coded into a serial, perceptible signal for the benefit of listeners who currently lack the information and have to integrate it piecemeal with what they know. After all, when one part of the brain is "talking to" another part, it does not have to encode the information into a serial format suitable for the vocal-acoustic channel; such communication takes place via massively parallel transmission. The visual system, for example, does not have to encode the retinal image into something like an ordered sequence of phonemes in order to communicate with the hippocampus or frontal lobes.

Indeed, if language were not designed for communication, the key tenet of Minimalism—that language consists of a mapping from meaning to sound—would not be a "virtual conceptual necessity," as Chomsky has repeatedly asserted, but an inexplicable coincidence. The only way to make sense of the fact that humans are equipped with a way to map between meaning and vocally produced sound is that it allows one person to get a meaning into a second person's head by making a sound with his or her vocal tract.

We note in addition that the innate aspect of the language faculty is for *learning* language from the community, not for *inventing* language. One cannot have inner speech without having words, and words above all are learned. (To be sure, people invent new words from time to time, but this is not the major source of their vocabulary). Moreover, the fact that the inner speech of deaf signers consists of signs rather than sounds follows from the assumption that inner language is based on learned outer language. If inner speech were primary, this too would be an unexplained coincidence. Turning to cases in which languages *are* invented, we find that Nicaraguan Sign Language, for example, arose in the context of a community seeking communication (Senghas & Coppola, 2001). Similarly, isolated deaf children who create home signs do so in the context of communication with others. We are unaware of cases in which deaf individuals develop a complex vocabulary and grammar just to talk to themselves. And without exception, other linguistic isolates do not develop speech at all (Pinker, 1994b).

This is not to deny that inner speech enhances thought (Jackendoff, 1996), and that this enhancement has been a major influence on the growth of civilization. But given that inner speech depends on having outer speech, acquired in a communicative situation, we are inclined to think that if anything is a by-product (or "spandrel") here, it is inner speech. The primary adaptation is communication, with enhanced thought as an additional benefit.

4.2. Language is "perfect"

Next let us consider the conjecture, central to the Minimalist Program, that language, though dysfunctional for communication, is a "perfect" or "optimal" mapping between sound and meaning, such that its form is structurally inevitable given what it has to bridge. As HCF express it, "FLN may approximate a kind of 'optimal solution' to the problem of linking the sensory-motor and conceptual–intentional systems" (1574). This conjecture is not easy to evaluate, because nothing is "perfect" or "optimal" across the board but only with respect to some desideratum. Let us consider the criteria that Chomsky defends in other recent writings.

Language is (mostly) like invented formal symbol systems. In one place, Chomsky explains his criterion for perfection as follows: "A good guiding intuition about imperfection is to compare natural languages with invented 'languages', invented symbolic systems. When you see differences, you have a suspicion that you are looking at something that is a prima facie imperfection" (Chomsky, 2000b, p. 109). This, however, assumes that invented symbolic systems are designed to satisfy the same desiderata as human language. But there is little reason to believe this. Human languages, unlike invented symbolic systems, must be used in real time and by agents with limitations of knowledge and computational capacity. Languages develop spontaneously in a community subject to the vagaries of history, rather than being stipulated by formal arbiters. And they must be induced by exposure to examples rather than being applied in explicit conformity with published standards. Any of these differences could explain why human languages might differ from invented symbolic systems, quite apart from matters of "imperfection."

In other places, Chomsky's notion of a "perfect" symbolic system involves intuitions about certain kinds of economy in the mapping between meaning and sound (for example, no meaningless grammatical elements left in Logical Form, short derivations preferred to long ones, and movement rules operating after phonological Spell-Out rather than before). Yet as we have noted, judged by other criteria that might be thought to characterize well-designed symbolic systems, language (as seen through the Minimalist lens) is anything but optimal. It appears to be computationally inefficient, because the processor must evaluate multiple possible derivations for entire sentences or at local choice points (Johnson & Lappin, 1997, 1999, chap. 3). And it is far from optimal in terms of parsimony of structure, given that Minimalist tree structures are packed with abstract and empty elements, in fact typically more of these than there are words.

Moreover, even by Chomsky's own criteria, language is full of "apparent imperfections," which he sees as challenges to be overcome by future research in the Minimalist framework. (Presumably such research will show them to be exigencies imposed by the semantic and phonological interfaces). Agreement and case are called "apparent imperfections," rather than basic design features of language (Chomsky, 2000b, p. 111); their virtues in free word order languages are ignored. Another "imperfection" is the fact that phrases are sometimes moved from their canonical positions, as in questions or passives. Calling this an "imperfection" ignores the fact (which Chomsky elsewhere notes) that movement allows sentences to use some aspects of word order to convey topic and focus while others convey who did what to whom (Chomsky, 2000a, p. 13). The principle that functional systems must trade off conflicting demands is absent from such reasoning; it is as if the "perfect" car is defined to be one that goes as fast as possible, and the tradeoffs against weight, braking, steering, safety, gas mileage, and cost are "apparent imperfections." Even more egregiously, "the whole phonological system looks like a huge imperfection, it has every bad property you can think of" (Chomsky, 2000b, p. 118). And "even the fact that there is more than one language is a kind of imperfection." (Chomsky, 2000b, p. 109). Quite so: there are thousands of different solutions to the problem of mapping from sound to meaning, and they cannot *all* be optimal.

Perhaps "optimal" is meant to refer to the general style of derivational solution. But, as we noted, languages use four different devices for conveying semantic relations: phrase structure, linear order, agreement, and case, often deployed redundantly. In this sense language is reminiscent of other cognitive systems such as depth perception, where multiple mechanisms compute the same output—the relative distance of objects in the visual field—in some situations redundantly and in some not. It looks as if evolution has found several solutions that ordinarily reinforce each other, with some predominating over others in special circumstances; in the case of language, the balance among them shifts depending on the language's history, the sentence's context, or both. If so, case and agreement are not "imperfections" at all, just alternative mechanisms to the same end as phrase order and hierarchy.

We conclude that the overall claim that language is "perfect" or "optimal" is a personal vision of how language ought to be characterized rather than an empirical discovery about the way language is. As such it cannot be used to motivate assertions about how language evolved.

Language exists in the only possible form that is usable. One might ask what the relevance of the possible "perfection" of language is to its evolution. The idea seems to be that nothing less than a perfect system would be in the least bit usable, so if the current language faculty is perfect, one could not explain its evolution in terms of incremental modification of earlier designs. Thus Chomsky (2000b, p. 58) asks "how closely human language approaches an optimal solution to design conditions that the system must meet to be usable at all." This echoes an earlier suggestion that "In the case of such systems as language or wings it is not easy even to imagine a course of selection that might have given rise to them. A rudimentary wing, for example, is not "useful" for motion but is more of an impediment. Why then should the organ develop in the early stages of evolution?" (Chomsky, 1988, p. 167).

The "What good is five percent of a wing?" argument has long been raised by creationists, and in every case has been answered by showing that intermediary structures in fact are useful (Dawkins, 1986; Pennock, 2000). In the case of language, pidgins are a key source of evidence. They are mappings of phonological structure to meaning that lack fixed word order, case, and agreement. They also lack subordinate clauses, which are the standard mark of recursion, and possibly lack phrase structure altogether. Yet they definitely are usable, though not as reliably as fully developed language. Bickerton (1990), Givon (1995), and Jackendoff (2002) suggest that modern language is a tuning up of evolutionary earlier systems resembling pidgins. The four major syntactic mechanisms for encoding meaning can be thought of as incremental improvements, each of which makes the system more reliable. There is a progression of functionality, not a dichotomy between one system that is "perfect" and other systems that are "not usable at all."

Language is non-redundant. Chomsky does adduce one criterion for "perfection" that is explicit and hence easier to evaluate, namely that language is not redundant:

> The general conclusion … is that language is designed as a system that is "beautiful" but in general unusable. It is designed for elegance, not for use, though with features that enable to it to be used sufficiently for the purposes of normal life.… Insofar as this is true, the system is elegant, but badly designed for use. Typically, biological systems are not like that at all. They are highly redundant, for reasons that have a plausible functional account.… Why language should be so different from other biological systems is a problem, possibly even a mystery (Chomsky, 1991).

The assertion that language displays little or no redundancy is puzzling. With regard to the speech waveform, one can high-pass, low-pass, or band-pass speech at various cutoffs, discarding non-overlapping pools of information, yet leave the speech perfectly intelligible; telephones would not work without this property (Green, 1976). With regard to recovering the meaning of words and sentences, one can rxmxve thx vxwxls, rexove exery xecoxd xonxonaxt, order the scramble words the of, or omit functional morpheme, and still retain partial (and sometimes total) intelligibility (Miller, 1967).[16] With regard to encoding meanings into words and sentences, there are several ways to do so, one can accomplish the task by multiple methods, and more than one means is available.

Chomsky occasionally has alluded to the alleged non-redundancy of lexical storage in memory: "Consider the way an item is represented in the lexicon, with no redundancy, including just what is not predictable by rule" (Chomsky, 2000b, p. 118). Chomsky has embraced this claim (which he attributes to Bloomfield (1933, p. 274) at least since *Aspects of the Theory of Syntax* (Chomsky, 1965, p. 214); the idea is that one should factor language into a set of rules which capture all redundancies and an irreducible residue that is stored in memory. But the idea appears to be less an empirical discovery than a methodological dictum, according to which characterizations of language are to be stated in as compressed a form as possible. Psycholinguistic experiments have uncovered numerous instances in which redundant information is stored in memory. For instance, although regularly inflected items can be constructed by rule, at least some regular forms can be shown to be stored redundantly with their stems (Baayen, Schreuder, de Jong, & Krott, 2002; Pinker, 1999, chap. 5; Ullman, 1999).

But even at the level of linguistic theory proper (without considering experiments), lexical entries appear to be significantly redundant. What would a truly non-redundant language look like? Presumably it would consist only of Saussurean, arbitrary lexical items like *red* and *coat* and rules that create compositional structures on demand, like *a red coat*, obviating the need for storage. But consider exocentric compounds (discussed in Jackendoff, 1997). Part of one's linguistic knowledge is that a *redcoat* is a British soldier of the 1770s who wore a red coat, a *yellowjacket* is a kind of wasp with a yellow "jacket," a *redhead* is a person with reddish hair, and a *blackhead* is a pimple with a black "head." The general rule for such Adjective–Noun compounds is that they have meanings of the form 'X with a Y that is Z', where Y is the meaning of the noun, Z the meaning of the adjective, and X has to be learned item by item. The *red* in the lexical entry for *redcoat* is clearly redundant with the lexical entry for *red* which combines freely with noun phrases: they are pronounced the same, both are adjectives, and both refer to colors in the same range. Likewise for two uses of *coat*. Moreover, speakers recognize that the word *redcoat* is not an arbitrary string of English phonemes but refers to someone who characteristically wore a red coat (that is, *redcoat* is not perceived as an arbitrary, non-redundant, sound-meaning pairing like *soldier*). At the same time, the word cannot be composed out of *red* and *coat* by a general compounding rule, because speakers also recognize that a *redcoat* is not just anyone attired in a rufous outergarment but specifically a late eighteenth-century British soldier. Similarly, speakers know that a *redhead* specifically has red *hair*, rather than a totally red head. This irreducible redundancy is widespread in human languages, such as in idioms, semiproductive derivational morphology, and families of irregular forms (Jackendoff, 1997; Pinker, 1999). If the claim that the lexicon is non-redundant has

[16] The following text has recently been circulating over the Internet: "Acocdrnig to an elgnsih unviesitry sutdy the oredr of letetrs in a wrod dosen't mttaer, the olny thnig thta's iopmrantt is that the frsit and lsat ltteer of eevry word is in the crcreot ptoision. The rset can be jmbueld and one is stlil able to raed the txet wiohtut dclftfuiiy."

any empirical content (rather than being the mathematical truism that a redundant representation can always be compressed and then reconstituted by an algorithm), the facts of English would seem to refute it.

Chomsky's claim that the putative non-redundancy of language poses a "mystery" for modern biology is part of a larger claim that current biology must be revamped to accommodate the findings of Minimalist linguistics:

> Any progress toward this goal [showing that language is a "perfect system"] will deepen a problem for the biological sciences that is far from trivial: how can a system such as language arise in the mind/brain, or for that matter, in the organic world, in which one seems not to find anything like the basic properties of human language? That problem has sometimes been posed as a crisis for the cognitive sciences. The concerns are appropriate, but their locus is misplaced; they are primarily a problem for biology and the brain sciences, which, as currently understood, do not provide any basis for what appear to be fairly well established conclusions about language (Chomsky, 1995, pp. 1–2).

Given the relative rigor and cumulativeness of biology and linguistics, this strikes us as somewhat presumptuous (especially since the Minimalist Program is "still just an 'approach'", "a conjecture about how language works").[17] There is a simpler resolution of the apparent incompatibility between biology and Minimalism, namely that Chomsky's recent claims about language have it backwards. Rather than being useless but perfect, language is useful but imperfect, just like other biological systems.

4.3. The narrow faculty language faculty evolved for reasons other than language

HCF speculate that recursion, which they identify as the defining characteristic of the narrow language faculty, may have "evolved for reasons other than language." Specifically, recursion could have evolved in other animals "to solve other computational problems such as navigation, number quantification, or social relationships," in a module that was "impenetrable with respect to other systems. During evolution, the modular and highly-domain-specific system of recursion may have become penetrable and domain-general. This opened the way for humans, perhaps uniquely, to apply the power of recursion to other problems" (HCF, 1578).

We note that the suggestion that recursion evolved for navigation (or other cognitive domains) rather than language, like the earlier suggestion that the vocal tract evolved for size exaggeration rather than speech, assumes a false dichotomy: that if a system originally underwent selection for one function, it did not undergo subsequent selection for some other function. Just as forelimbs originally were selected for stability in water and subsequently were selected for flight, legged locomotion, or grasping, certain circuitry

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[17] We concur that language does raise challenges for neurobiology, in particular, how neural networks can implement the kinds of computation found in language and the parts of cognition it interfaces with, especially the recursive concatenation of symbols and instantiation of variables (Jackendoff, 2002, chap. 3; Marcus, 2001; Pinker, 1997, chap. 2). However, Chomsky's quotation refers specifically to the claim that "language is something like a 'perfect system'" (p. 1).

could have been shaped by selection for (say) navigation and subsequently have been *re*shaped by selection for language.

But even if we allow for the possibility of selection before, during, and after a change of function, the suggestion that the system for linguistic recursion is a minor modification of a system for navigation is questionable. Although Chomsky frequently characterizes linguistic recursion as "discrete infinity," the two principal navigation systems documented in non-human animals (Gallistel, 1990) show no such property. Dead reckoning is infinite but not discrete; recognition of landmarks is discrete but not infinite.

As for recursion in language evolving out of recursion in number cognition, if this involves co-opting at all (see Grinstead et al., 1997, 2004, for doubts), the proposed direction in HCF's hypothesis would appear to be backwards (Bloom, 1994a; Dehaene, Spelke, Pinel, Stanescu, & Tsivkin, 1999; Wiese, 2004). Recursive language is a human universal or near-universal, emerging reliably and spontaneously in ontogeny. But recursive number cognition is not. The majority of human cultures, like all animal species, do not have recursive number systems (or at least did not until recent incursions of Western civilization), but instead quantify objects using a system for estimating analogue amounts and a system for categorizing a finite number of small numerosities (Dehaene, 1997; Wiese, 2004). Those that have developed recursive number systems in their cultural history may have exapted them from the recursive properties of language, rather than vice-versa.

We do agree with HCF that recursion is not unique to language. Indeed, the only reason language *needs* to be recursive is because its function is to express recursive *thoughts*. If there were not any recursive thoughts, the means of expression would not need recursion either. So here we join HCF in inviting detailed formal study of animal cognition and other human capacities to ascertain which abilities require recursive mental representations and which do not. Plausible candidates include music (Lerdahl and Jackendoff, 1983), social cognition (touched on in Jackendoff, 1992, in press), visual decomposition of objects into parts (Marr, 1982), and the formulation of complex action sequences (Badler et al., 1999; Jackendoff, in press; Miller, Galanter, & Pribram, 1960; Schank and Abelson, 1975).

Here the problem is not a paucity of candidates for evolutionary antecedents but a surfeit. As Herbert Simon has pointed out (Simon, 1969), probably all complex systems are characterized by hierarchical organization. So if "recursion" is identified with hierarchical decomposition and used as a criterion for identifying some pre-existing cognitive function as a source for exaptation to language, speculations can proliferate unconstrained.

We also wish to point out that language is not just any old recursive system but embodies at least four additional design constraints. First, its recursive products are temporally sequenced, unlike those of social cognition or visual decomposition. Second, syntactic trees have a characteristic structure, in which each constituent contains a distinguished member, the head, which determines the category and semantic referent of the constituent, and around which the other elements are grouped as arguments and modifiers (this is the basis of the X-bar theory of phrase structure). Third, syntax is not just a recursive representational system externalized. It maps multi-directionally (in production and comprehension) *among* systems: recursive semantic representations, recursive communicative intentions, and hierarchial phonological signals. Fourth, the details of the recursive structures are largely arbitrary and learned, conforming to the words and constructions of the linguistic community, rather than being dictated by immediate real-world constraints such as how a scene is put together or which sequence of actions is physically capable of effecting a goal. As such, language is unlikely to be just a straightforward exaptation of a single pre-existing recursive system such as visual cognition, motor control, or social relationships. Rather, it appears to be a kind of interface or connective tissue among partly pre-existing recursive systems, mapping among them in an evolutionarily novel manner.

In sum, we find HCF's case that language is not an adaptation for communication unconvincing. The argument that presupposes the Minimalist Program to conclude that language is too simple to require invoking natural selection is circular, because this is a desideratum that the MP hopes to fulfill (in the teeth of much counterevidence), rather than a discovery it has established. The argument that language is no better designed for communication than hair styles is belied by the enormously greater expressive power of language and the fact that this power is enabled by the grammatical machinery that makes language so unusual. The argument that language is designed for interior monologues rather than communication fails to explain why languages map meaning onto sounds and why they must be learned from a social context. The argument that language is "perfect" or "optimal" has never been stated clearly, and is, by Chomsky's own admission, apparently refuted by many "imperfections." The argument that language is not redundant is false in every domain in which it can be evaluated. Finally, the suggestion that the recursive power of language arose as a simple co-opting of recursion in other cognitive systems such as navigation or number encounters numerous problems: that navigation is not discretely infinite; that recursive number cognition is parasitic on language rather than vice-versa; and that language maps *among* recursive systems rather than being a straightforward externalization of a single recursive system.

The alternative in which language is an adaptation for the communication of knowledge and intentions faces none of these problems. It is consistent with behavioral and genetic evidence that language shows multiple signs of partial specialization for this task rather than grafting one component (recursion) onto a completely unchanged primate base. It is based on defensible conclusions about the nature of language established by existing linguistic research rather than a promissory program that is admittedly incompatible with the facts. It does not require tendentious claims such as that language is non-redundant, perfect, unsuited for communication, or designed for beauty rather than use. It meshes with other features of human psychology that make our species unusual in the animal kingdom, namely a reliance on acquired technological know-how and extensive cooperation among non-kin. And it does not imply that linguistics poses a crisis for biology but rather helps bring them into consilience.

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