Language as an Adaptation by Natural Selection

Steven Pinker
Harvard University

This paper defends the theory that the human language faculty is a biological adaptation and, like other examples of complex adaptive design in the natural world, it is a product of natural selection. Language is designed to code propositional information for the purpose of sharing it with others, and thus fits with other features of the distinctive human "cognitive niche" including cause-and-effect thinking and hypersociality. Finally, the paper demonstrates that these and other evolutionary hypotheses about language as an adaptation have been supported by two new areas of research: evolutionary game theory, and tests for selection in molecular evolution.

Keywords: language evolution, adaptation, natural selection, evolutionary game theory, molecular evolution.

语言——自然选择的一种适应

该文认为人类的语言能力是一种生物学意义上的适应，是自然选择的产物。人类的语言与自然界中其它复杂的生物学适应相类似，也具有特定的机能。语言的特定机能在于编码叙事性信息并与他人分享，这与人类认知活动中因果推理所具有的高度社会性特点相一致。两个新的研究领域，进化博弈理论和分子进化选择理论，都证实了语言是一种受到自然选择的进化适应。

关键词：语言进化，适应，自然选择，进化博奕论，分子进化论。

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In this paper, I will address three questions about language evolution. Why is language an adaptation? What might language be an adaptation for? What are ways to test the theory of language as an adaptation? Answers to these questions are intended to be simple and straightforward, whereas more extended answers can be found in other writings of mine (e.g., Pinker, 2003) from which this article is adopted. To answer the first question, I present below evidence in support of language as a distinct part of the human phenotype as well as evidence against means other than natural selection by which language evolved.

Language is a Distinct Part of the Human Phenotype

Oppositions to the theory that language is an adaptation include the argument that language is a manifestation of more general cognitive abilities, such as "general intelligence," "a symbolic capacity," or "cultural learning" (e.g., Deascon, 1997; Tomasello, 1999). Although it is difficult to say what "cultural learning" or "general intelligence," really imply, one can determine whether mastery of language in the human species resembles abilities that are unambiguously culturally acquired, like agricultural techniques, chess skill, and mathematical expertise, or whether it looks more like a part of the standard human phenotype, like fear, humor, or sexual desire. Some very general properties of the natural history of

language suggests that the latter is more accurate (see Jackendoff, 2002; Lightfoot & Anderson, 2002; Pinker, 1994).

First, language is universal across societies and across neurological normal people within a society, unlike far simpler skills like farming techniques or chess. There may be technologically primitive peoples, but there are no primitive languages: the anthropologists who first documented the languages of nonstate societies a century ago were repeatedly astonished by their complexity and abstractness (Voegelin & Voegelin, 1977). And despite stereotypes to the contrary, the language of uneducated, working class, and rural speakers has been found to be systematic and rule-governed, though the rules may belong to dialects that differ from the standard one (Labov, 1969; McWhorter, 2003).

Second, languages conform to a universal design. A language is not just any conceivable code that maps efficiently from sound to meaning. Design features such as subtle and complex properties of grammar can be found in all human languages (Baker, 2001; Comrie, 1981; Greenberg, Ferguson, & Moravcsik, 1978; Hockett, 1960).

A third kind of evidence is the ontogenetic development of language. Children the world over pass through a universal series of stages in acquiring a language (Brown, 1973; Ingram, 1989; Pinker, 1994). That sequence culminates in mastery of the local tongue, despite the fact that learning a language requires solving the daunting problem of taking in a finite sample of sentences (speech from parents) and

inducing a grammar capable of generating the infinite language from which they were drawn (Pinker, 1979; Pinker, 1984). Moreover, children's speech patterns, including their errors, are highly systematic, and often can be shown to conform to linguistic universals for which there was no direct evidence in parents' speech (Crain, 1991; Gordon, 1985; Kim et al., 1994).

A fourth kind of evidence also comes from the study of language acquisition. If children are put together without a pre-existing language that can be "culturally transmitted" to them, they will develop one of their own. One example, studied by Bickerton, comes from the polyglot slave and servant plantations in which the only "language" among adults was a pidgin, a makeshift communicative system with little in the way of grammar. The children in those plantations did not passively have the pidgin culturally transmitted to them, but quickly developed creole languages, which differ substantially from the pidgins and which have all the basic features of established human languages (Bickerton, 1981). Another example comes from deaf communities, where complex sign languages emerge quickly and spontaneously. A recent study in Nicaragua has tracked the emergence of a complex sign language in little more than a decade, and has shown that the most fluent and creative users of the language were the children (Senghas & Coppola, 2001).

A fifth kind of evidence is that language and general intelligence seem to be doubly dissociable in neurological and genetic disorders. In aphasias and in the genetically caused developmental syndrome called Specific Language Impairment, intelligent people can have extreme difficulties speaking and understanding (Leonard, 1998; Siegal, Varley, & Want, 2001; van der Lely, Rosen, & McClelland, 1998). Conversely, in a number of retardation syndromes, such as Williams syndrome, substantially retarded children may speak fluently and grammatically and do well on tests of grammatical comprehension and judgment (Clahsen & Almazen, 1998; Curtiss, 1989; Rossen, Klima, Bellugi, Bihrle, & Jones, 1996). Few of these dissociations are absolute, with language or nonlinguistic cognition completely spared or completely impaired. But the fact that the two kinds of abilities can dissociate quantitatively and along multiple dimensions shows that they are not manifestations of a single underlying ability.

Evidence Against Means Other than Natural Selection

Against the hypothesis that language is an adaptation is the argument that it evolved by mechanisms other than natural selection (Chomsky, 1988; Gould, 1997; see Piatelli-Palmarini, 1989 and Pinker & Bloom, 1990 for discussion). On this view, language may have evolved all at once as the product of a macromutation. Or the genes promoting language may have become fixed by random genetic drift or by genetic hitchhiking (i.e., genes that were near other genes that were the real target of selection). Or it may have arisen as a by-product of some other evolutionary development such as a large brain.

One appeal of these nonselectionist theories is a general misconception, spread by Gould (Gould & Lewontin, 1979), that natural selection has become an obsolete or minor concept in evolutionary biology, and that explanations in terms of by-products (called "spandrels") or physical constraints are to be preferred in principle (e.g., Piatelli-Palmarini, 1989). This is a misconception because natural selection remains the only evolutionary force capable of generating complex adaptive design, in which a feature of an organism (such as the eye or heart) has a nonrandom organization that enables it to attain an improbable goal that fosters survival and reproduction (Dawkins, 1986; Williams, 1966). Moreover, natural selection is a rigorous concept which can be modeled mathematically or in computer simulations, measured in natural environments, and detected by statistical analyses of organisms' genomes (Kreitman, 2000a; Maynard Smith, 1988; Przeworski, Hudson, & Di Rienzo, 2000; Weiner, 1994).

A second appeal of nonselectionist theories comes from a skepticism that language could have provided enough reproductive benefits to have been selected for. According to one objection, popular among linguists, language has arbitrary features that do not obviously contribute to communication. However, *all* communication systems have arbitrary features (such as the particular sequences of dots and dashes making up Morse code), because arbitrary ways of linking messages to signals are useful as long as they are shared by sender and recipient. Moreover, since a feature that eases the task of the speaker (by omitting information or reducing the complexity of the signal) will complicate the task of the listener (by making the message more ambiguous or vulnerable to noise), a shared code must legislate arbitrary conventions that do not consistently favor any single side or direction (Pinker & Bloom, 1990).

Another argument for nonselectionist theories is that grammar is more complicated than it needs to be to fulfill the communicative needs of a hunter-gatherer lifestyle. However, as Pinker and Bloom (1990) pointed out, complex grammar "makes a big difference whether a far-off region is reached by taking the trail that is in front of the large tree or the trail that the large tree is in front of. It makes a difference whether that region has animals that you can eat or animals that can eat you." Since selection can proceed even with small reproductive advantages (say, one percent), the evolution of complex grammar presents no paradox.

A third misconception is that if language is absent from chimpanzees, it must have evolved by a single macromutation. This argument is based on a misunderstanding of how evolution works. Chimpanzees and bonobos are our closest living relatives, but that does not mean that we evolved from them. Rather, humans evolved from an extinct common ancestor that lived six to eight million years ago. There were many other (now-extinct) species in the lineage from the common ancestor to modern humans (australopithecines, *habilis, ergaster,* archaic *sapiens*, etc.), and more important, many individuals making up the lineages that we group into species for convenience. Language could well have evolved gradually *after* the chimp-human split, in the 200,000–300,000 generations that make up the lineage leading to modern humans. Language could be an autapomorphy: a trait that evolved in one lineage but not its sister lineages.

The final appeal of the nonselectionist hypothesis is that language could only have been useful once it was completely in place: a language is useless if you are the only one to have evolved the ability to speak it. But this objection could be raised about the evolution of *any* communicative system, and we know that communication has evolved many times in the animal kingdom. The solution is that comprehension does not have to be in perfect synchrony with production. In the case of language, it is often possible to decode parts of an utterance in a language one has not completely mastered. When some individuals are making important distinctions that can be decoded by listeners only with cognitive effort, it could set up a pressure for the evolution of neural mechanisms that would make this decoding process become increasingly automatic and effortlessly learned (Pinker & Bloom, 1990). The process whereby environmentally-induced responses set up selection pressures for such responses to become innate, triggering conventional Darwinian evolution that superficially mimics a Lamarckian sequence, is known as the Baldwin Effect (Hinton & Nowlan, 1987).

Opposing these spurious arguments for the nonselectionist hypothesis is the standard argument in evolutionary biology that only natural selection can explain the evolution of complex adaptive design (Dawkins, 1986; Williams, 1966). The information processing circuitry necessary to produce, comprehend, and learn language requires considerable organization. Randomly organized neural networks, or randomly selected subroutines from an artificial intelligence library, do not give rise to a system that can learn and use a human language. Language is not just a set of symbolic labels for concepts, not just the use of linear order, not just the use of hierarchical structure, and not just a blurting out of a sequence of sounds. It is an integrated system containing a lexicon, several components of grammar, and interfaces to input-output systems, possibly with language-specific modifications of their own. And this complexity is not just there for show, but makes possible a remarkable ability: language's vast expressive power, rapid acquisition by children, and efficient use by adults.

As with other complex organs that accomplish improbable feats, the necessary circuitry for language is unlikely to have evolved by a process that is insensitive to the functionality of the end product, such as a single mutation, genetic drift, or arbitrary physical constraints. Natural selection is the most plausible explanation of the evolution of language, because it is the only physical process in which how well something works can explain how it came into existence.

Turning now to the second question, if language is an adaptation, what is it an adaptation for? Note that this is different from the question of what language is typically *used* for, especially what it is used for at present. It is a question about the "engineering design" of language and the extent to which it informs us about the selective pressures that shaped it. I argue below that language serves and is part of the cognitive niche that consists of three key features of the distinctively human lifestyle – know-how, sociality, and language – with each coevolving and constituting a selection pressure for the others.

Language as Part of the Cognitive Niche

Language appears as if it was put together to encode propositional information -- who did what to whom, what is true of what, when, where and why -- into a signal that can be conveyed from one person to another. It is not hard to see why it might have been adaptive for a species with the rest of our characteristics to evolve such an ability. The structures of grammar are well suited to conveying information about technology, such as which two things can be put together to produce a third thing; about the local environment, such as where things are; about the social environment, such as who did what to whom, when where and why; and about one's own intentions, such as "If you do this, I will do that," which accurately convey the promises and threats that undergird relations of exchange and dominance.

Gathering and exchanging information is, in turn, integral to the larger niche that modern *Homo sapiens* has filled, which John Tooby and Irven DeVore (Tooby & DeVore, 1987) have called "the cognitive niche." Tooby and DeVore developed a unified explanation of the many human traits that are unusual in the rest of the living world. They include our extensive manufacture of and dependence on complex tools, our wide range of habitats and diets, our extended childhoods and long lives, our

hypersociality, our complex patterns of mating and sexuality, and our division into groups or cultures with distinctive patterns of behavior. Tooby and DeVore proposed that the human lifestyle is a consequence of a specialization for overcoming the evolutionary fixed defenses of plants and animals by cause-and-effect reasoning. Such reasoning enables humans to invent and use new technologies that exploit other living things before they can develop defensive countermeasures in evolutionary time. This cause-and-effect reasoning depends on intuitive theories about various domains of the world, such as objects, forces, paths, places, manners, states, substances, hidden biochemical essences, and other people's beliefs and desires.

The information captured in these intuitive theories is reminiscent of the information that the machinery of grammar is designed to convert into strings of sounds. It cannot be a coincidence that humans are special in their ability to outsmart other animals and plants by cause-and-effect reasoning, and that language is a way of converting information about cause-and-effect and action into perceptible signals.

Tooby and DeVore have pointed out that a species that has evolved to rely on information should thus also evolve a means to *exchange* that information. Language multiplies the benefit of knowledge, because a bit of know-how is useful not only for its practical benefits to oneself but as a trade good with others. Using language, I can exchange knowledge with somebody else at a low cost to myself and hope to get something in return. It can also lower the original acquisition cost − I can learn about how to catch a rabbit from someone else's trial and error, without having to go through it myself.

A possible objection to this theory is that organisms are competitors, so sharing information is costly because of the advantages it gives to one's competitors. If I teach someone to fish, I may still know how to fish, but they may now overfish the local lake, leaving no fish for me. But this is just the standard problem of the evolution of any form of cooperation or altruism, and the solution in the case of language is the same. By sharing information with our kin, we help copies of our genes inside those kin, including genes that make language come naturally. As for non-kin, if we inform only those people who are likely to return the favor, both of us can gain the benefits of trade. It seems clear that we do use our faculties of social cognition to ration our conversation to those with whom we have established a nonexploitative relationship.

Language, therefore, meshes neatly with the other features of the cognitive niche. The zoologically unusual features of *Homo sapiens* can be explained parsimoniously by the idea that humans have evolved an ability to encode information about the causal

structure of the world and to share it among themselves. Our hypersociality comes about because information is a particularly good commodity of exchange that makes it worth people's while to hang out together. Our long childhood and extensive biparental investment are the ingredients of an apprenticeship: before we go out in the world, we spend a lot of time learning what the people around us have figured out. And because of the greater payoff for investment in children, fathers, and not just mothers, have an incentive to invest in their children. This leads to changes in sexuality and to social arrangements (such as marriage and families) that connect men to their children and to the mothers of those children.

Humans depend on culture, and culture can be seen in part as a pool of local expertise. Many traditions are endemic to a people in an area because know-how and social conventions have spread via a local network of information sharing. Humans have evolved to have a long lifespan so that investment into extended pre-reproductive training and learning can be put to use for a longer time. Finally, the reason that humans can inhabit such a wide range of habitats is that our minds are not adapted to a narrow, specialized domain of knowledge, such as how to catch a rabbit. Our knowledge is more abstract, such as how living things work and how objects collide with and stick to each other. That mindset for construing the world can be applied to many kinds of environments rather than confining us to a single ecosystem.

Several alternative hypotheses acknowledge that language is an adaptation but disagree on what it is an adaptation for. One possibility, inspired by an influential theory of the evolution of communication by Dawkins and Krebs (Dawkins, 1982), is that language evolved not to inform others but to manipulate and deceive them. The problem with this theory is that unlike signals with the physiological power to manipulate another organism directly, such as loud noises or chemicals, the signals of language are impotent unless the recipient actively applies complicated computations to decode them. It is impossible to use language to manipulate someone who does not understand the language.

Another possibility is that language evolved to allow us to think rather than to communicate. According to one argument, it is impossible to think at human levels of complexity without a representational medium for propositions, and language is that medium (Bickerton, 1990). According to another argument, we spend more time talking to ourselves than talking to other people, so if language has any function at all, it must be thought rather than communication (Chomsky, 2002). These theories have two problems. One is that they assume

the strongest possible form of the Whorfian hypothesis—that thought depends entirely on language—which is unliklely for a number of reasons (see Pinker, 1994; Pinker, 2002; Siegal et al., 2001; Weiskrantz, 1988). The other is that if language evolved to represent information internally, much of the apparatus of grammar, which converts logical relationships into perceptible signals, would be superfluous. Language would not need rules for defining word orders, case markers, phonological strings, adjustment rules, and so on, because the brain could more efficiently code the information to itself silently using tangled networks of a variables and pointers.

Considerations of language design rule out other putative selectional pressures. Language is unlikely to have evolved as a direct substitute for grooming (Dunbar, 1998), or as a courtship device to advertise the fitness of our brains (Miller, 2000), because such pressures would not have led to an ability to code complex abstract propositions into signals. A fixed set of greetings would suffice for the former; meaningless displays of virtuosity would suffice for the latter.

Are there ways to test the theory that language is an adaptation? Contrary to the common accusation that evolutionary hypotheses, especially ones about language, are post hoc "just-so" stories, the hypothesis that language is an evolutionary adaptation can be made rigorous and put to empirical test. Below I present two new areas of research on the evolution of language that are beginning to support the theory that language is an adaptation.

Language and Evolutionary Game Theory

Evolutionary game theory has allowed biologists to predict how organisms ought to interact with other organisms coevolving their own strategies (Maynard Smith, 1982). Language, like sex, aggression, and cooperation, is a game it takes two to play, and game theory can provide the external criteria for utility enjoyed by the rest of evolutionary biology. Modelers assume only that the transmission of information between partners provides them with an advantage (say, by exchanging information or coordinating their behavior), and that the advantage translates into more offspring, with similar communicative skills. The question then is how a stable communication system might evolve from repeated pairwise interactions, and crucially, whether such systems have the major design features of human language.

The first such attempt was a set of simulations by Hurford showing that one of the defining properties of human language, the arbitrary, bi-directional sign, will drive out other schemes over evolutionary time (Hurford, 1989). More recently, Nowak and his collaborators have now done the same for two of the other central design features of language (Nowak &

Krakauer, 1999; Nowak, Krakauer, & Dress, 1999a; Nowak, Plotkin, & Jansen, 2000).

Nowak and his colleagues pointed out that in all communication systems, errors in signaling or perception are inevitable, especially when signals are physically similar. Imagine organisms that use a different sound (say, a vowel) for every concept they wish to communicate. As they communicate more concepts, they will need additional sounds, which will be physically closer and hence harder to discriminate. At some point adding new signals just makes the whole repertoire more confusable and fails to increase its net communicative power. Nowak and colleagues showed that this limitation can be overcome by capping the number of signals and stringing them together into sequences, one *sequence* per concept. The sequences are what we call words, and the combination of meaningless vowels and consonants into meaningful words by rules of phonology is a universal property of language. Nowak and his colleagues have shown how its evolution is likely among communicators with a large number of messages to convey, a precondition that plausibly characterizes occupants of the cognitive niche.

Nowak and his colleagues have recently motivated another hallmark of language. Imagine a language in which each message was conveyed by a single word. For any word to survive in a community, it must be used frequently enough to be heard and remembered by all the learners. As new words are added to the vocabularies of speakers, old words must be used less often, and they are liable to fade, leaving the language no more expressive than before. Nowak et al. point out that this limitation can be overcome by communicators who use compositional syntax: rather than pairing each word with an entire event, they pair each word with a *component* of an event (a participant, an action, a relationship), and string the words together in an order that reflects their roles (e.g., *Dog bites man*). Such communicators need not memorize a word for every event, reducing the word-learning burden and allowing them to talk about events that lack words. Syntax and semantics, the other half of the duality of patterning, will evolve.

Nowak et al. note that syntax has a cost: the requirement to attend to the order of words. Its benefits exceed the costs only when the number of events worth communicating exceeds a threshold. This "syntax threshold" is most likely to be crossed when the environment, as conceptualized by the communicators, has a combinatorial structure: for example, when any of a number of actors (dogs, cats, men, women, children) can engage in any of a number of actions (walking, running, sleeping, biting). In such a world, the number of words that have to be learned by a syntactic communicator equals the sum of the number of actors, actions, places, and so on, whereas

the number that must be learned by a nonsyntactic communicator equals their *product*, a potentially unlearnable number. Nowak et al. thus proved the theoretical soundness of the conjecture of Pinker and Bloom (1990) that syntax is invaluable to an analytical mind in a combinatorial world.

Language and Molecular Evolution

Mathematical models and computer simulations can show that the advantages claimed for some feature of language really can evolve by known mechanisms of natural selection. These models cannot, of course, show that language *in fact* evolved according to the proposed scenario. But recent advances in molecular and population genetics may provide ways of testing whether selection in fact occurred.

Evolution is a change in gene frequencies, and the first prediction of the theory that language is an evolutionary adaptation is that there should be genes that have as one of their distinctive effects the development of normal human language abilities. Such a gene would be identifiable as an allelic alternative to a gene that leads to an impairment in language.

Clinical psycholinguists have long known of the collection of syndromes called Specific Language Impairment (SLI), in which a child fails to develop language on schedule and struggles with it throughout life (Bishop, North, & Donlan, 1995; Leonard, 1998; van der Lely et al., 1998). SLI runs in families and is more concordant in monozygotic than in dizygotic twins, suggesting it has a heritable component (Bishop et al., 1995; Stromswold, 2001; van der Lely & Stollwerck, 1996). But the inheritance patterns are usually complex, and until recently little could be said about its genetic basis. In 1990 investigators described a large multi-generational family, the KEs, in which half the members suffered from a disorder of speech and language, distributed within the family in the manner of an autosomal dominant gene (Hurst, Baraitser, Auger, Graham, & Norell, 1990) and subsequent work also rules out cognitive deficiency or motor problems as confounding factors (Bishop, 2002; Lai, Fisher, Hurst, Vargha-Khadem, & Monaco, 2001).

In 2001, geneticists identified a gene on Chromosome 7, FOXP2, that is perfectly associated with the syndrome within the KE family and in an unrelated individual (Lai et al., 2001). They also argued on a number of grounds that the normal allele plays a causal role in the development of the brain circuitry underlying language and speech, rather than merely disrupting that circuitry when mutated.

A second crucial prediction of the language-as-adaptation theory is that there should be *many* genes for language. If human language can be installed by a single gene, there would be no need to invoke natural selection, because it is not staggeringly improbable that a single gene could have reached fixation by genetic drift or hitchhiking. But if a large set of coevolved genes is necessary, probability considerations would militate against such explanations. The more genes are required for normal language, the lower the odds that our species could have accumulated them all by chance.

It seems increasingly likely that in fact many genes are required. In no known case of SLI is language wiped out completely, as would happen if language was controlled by a single gene which occasionally is found in mutated form. With recent advances in genomics, the polygenic nature of language is likely to become more firmly established. For example, two novel loci (distinct from FOXP2) were discovered in 2002 that are highly associated with SLI but not associated with low nonlinguistic intelligence (The_SLI_Consortium, 2002). Moreover, the two loci were associated with different aspects of language impairment, one with the ability to repeat nonwords, the other with expressive language, further underscoring the genetic complexity of language.

The most important prediction of the adaptation theory is that language should show evidence of a history of selection. The general complaint that evolutionary hypotheses are untestable has been decisively refuted by the recent explosion of quantitative techniques that can detect a history of selection in patterns of statistical variation among genes (Kreitman, 2000b; Przeworski et al., 2000). The tests depend on the existence of neutral evolution: random substitutions of nucleotides in noncoding regions of the genome, or substitutions in coding regions that lead to synonymous codons. These changes have no effect on the organism's phenotype, and hence are invisible to natural selection. The genetic noise caused by neutral evolution can thus serve as a baseline or null hypothesis against which the effects of selection (which by definition reduces variability in the phenotype) can be measured.

For example, if a gene has undergone more nucleotide replacements that alter its protein product than replacements that do not, the gene must have been subject to selection based on the function of the protein, rather than having accumulated mutations at random, which should have left equal numbers of synonymous and amino-acid-replacing changes. Alternatively, one can compare the variability of a gene among the members of a given species with the variability of that gene across species; a gene that has been subjected to selection should vary more between species than within species. Still other techniques compare the variability of a given gene to estimates of the variability expected by chance, or check whether a marker for an allele is found in a region of the

chromosome that shows reduced variation in the population because of a selective sweep. About a dozen such techniques have been devised so far. The calculations are complicated by the fact that recombination rate differences, migrations, population expansions, and population subdivisions can also cause deviations from the expectations of neutral evolution, and therefore can be confused with signs of selection. But techniques to deal with these problems have been developed as well.

It is now obvious how one can test the language-as-adaptation hypothesis (or indeed, any hypothesis about a psychological adaptation). If a gene associated with a trait has been identified, one can measure its variation in the population and apply the tests for selection. In 2002, the first of such tests was reported in *Nature* (Enard et al., 2002). A team of geneticists examined the FOXP2 protein (the cause of the KE family's speech and language disorder) in the mouse, several primate species, and several human populations. They found that the protein is highly conserved among mammals: the chimpanzee, gorilla, and monkey versions of the protein are identical to each other and differ in only one amino acid from the mouse version and two from the human version. But two of the three differences between humans and mice occurred in the human lineage after its separation from the common ancestor with the chimpanzee. And though the variations in the gene sequence among all the nonhuman animals produce few if any functional differences, at least one of the changes in the human lineage significantly altered the function of the protein. Moreover, the changes that occurred in the human lineage have become fixed in the species: the team found essentially no variation among 44 chromosomes originating in all the major continents, or in an additional 182 chromosomes of European descent. The statistical tests showed that these distributions are extremely unlikely to have occurred under a scenario of neutral evolution, and therefore that the FOXP2 genes has been a target of selection in human evolution. The authors further showed that the selection probably occurred during the last 200,000 years, the period in which anatomically modern humans evolved, and that the gene was selected for directly, rather than hitchhiking on an adjacent selected gene. Alternative explanations that rely on demographic factors were tested and at least tentatively rejected.

This stunning discovery does not *prove* that language is an adaptation, because it is possible that FOXP2 was selected only for its effects on orofacial movements, and that its effects on speech and language came along for the ride. But this is implausible given the obvious social and communicative advantages that language brings, and the fact that language deficiency is known to saddle the sufferers with educational and social problems (Beitchman et al., 1994; Snowling, Adams, Bishop, & Stothard, 2001).

Conclusion

In this paper I have defended the theory (first outlined and explicitly defended by Pinker and Bloom, 1990) that the human language faculty is a complex biological adaptation that evolved by natural selection for communication in a knowledge-using, socially interdependent lifestyle. To answer the question of what language is an adaptation for, I have shown that language serves and is part of the cognitive niche that defines unique human lifestyle. Finally, I reviewed two areas of research in which the theory that language is an adaptation can be empirically tested. In conclusion, I make the additional prediction that evolutionary game theory will assess the selective rational for an increasing number of universal properties of human language, and that new genes for language disorders and individual variation in language will be discovered and submitted to tests for a history of selection in the human lineage. In this way, the theory that language is an adaptation, motivated originally by the design features and natural history of language, will become increasingly rigorous and testable.

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