Reverse-engineering the Language Faculty Origins and Implications of the Minimalist Program*

Dennis Ott†

Abstract

Within the minimalist paradigm, narrow syntax is assumed to be a simple recursive generator without any non-nomological constraints, while the sources of linguistic complexity are the interfaces to performative systems. Linguistic theory moves beyond explanatory adequacy insofar as it succeeds in reducing structural specificities of grammar to universal principles of efficient generation and constraints imposed by mental architecture; the aim is defined as *principled explanation*, not data coverage. This paper examines some conceptual underpinnings of the Minimalist Program, suggesting that it is the most promising research paradigm in view of current understanding of language use and evolution.

One of the milestones of modern cognitive science is a debate between Noam Chomsky and Jean Piaget that took place about thirty years ago, carefully documented by Massimo Piattelli-Palmarini [1]. Chomsky argued against Piaget's constructivist psychology, which held that human cognition is constructed on the basis of our experience of the world: structure and complexity, according to this view, is imposed on the mind by the external world, molding it in successive stages of development.

Chomsky's view of cognitive development largely eliminated the belief in an external program for language—the belief that the source of structure is the external world, not internal to the mind. The program, Chomsky claimed, is in the make-up of the mind itself, specified by an innate *bauplan*. For the domain of language and cognition, it is the *internal* program, not some external program, that shapes the general course of development. This is the view that is standard in theoretical biology, and thus Chomsky's argument is an expression of his belief that linguistics and cognitive science are really subdisciplines of biology, in accord with his fundamental tenet that we should "study the acquisition of a cognitive structure such as language more or less as we study some complex bodily organ," given that "human cognitive systems . . . prove to

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†Department of Linguistics, Harvard University, Boylston Hall 3^{rd} floor, Cambridge, MA 02138. E-mail: dott@fas.harvard.edu.

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be no less marvelous and intricate than the physical structures that develop in the life of the organism" [2, p. 10].[1]

Ever since, the internal structure of the language organ is the subject of heated debate. Perhaps the greatest success of this debate is the framework of Principles and Parameters [5, 6, 7], which provides a conceptual basis for theories of language to capture the superficial tension between the uniform linguistic ability of our species and the variety of its actual expression—Universal Grammar (UG) on the one hand and the languages of the world on the other. The framework states that while all languages share abstract principles that are deeply rooted in our biological constitution, these principles are parametrized to allow for a limited linguistic *morphospace*, to borrow a term from evolutionary developmental biology. In this view, the innate endowment determines the set of possible languages, while external data plays a limited role in the selection from this set [8, 9, 10].[2]

Principles and Parameters allows for no coherent conception of an external program for language in Piaget's sense, limiting the role of external data severely. A "poverty of the stimulus", often taken to be a controversial assumption, is in fact what we expect as soon as we consider the Language Faculty an organ of the body: for the development of organs, be they cognitive or bodily, it is generally assumed that the external input relevant for the system (be it nutrition, linguistic data, visual stimuli, etc.) is not sufficient for its development, just like my car key is not sufficient for my car to work properly—nevertheless, I need the key to get the engine started. Equally, nobody would claim that visual stimuli are sufficient for the development of the visual system; as Hubel and Wiesel famously demonstrated, there must be an internal program and corresponding structures in the first place. The same must be assumed in the case of language [11, ch. 3].

The cognitive science of language seeks to answer the questions what the mechanisms underlying our use of language are, how these mechanisms arise in the individual, and, ideally, how they arose in the evolutionary history of our species. Before we turn to these questions, let me introduce some useful terminology.

A few years ago, Marc Hauser, Noam Chomsky and Tecumseh Fitch published an influential paper, titled "The faculty of language" [12]. They ask the question which components of our linguistic abilities are uniquely human, and which components, or close analogues of those, can be found in other species. The paper spawned a lot of controversy, most of it based on misunderstandings and conflations, which I will not go into here. Rather, I would like to adopt Hauser, Chomsky and Fitch's terminological move to separate what they call Faculty of Language in the Narrow Sense (FLN) and Faculty of Language in the Broad Sense (FLB). Despite the many misunderstandings surrounding this distinction, I think it is useful, in fact essential for the biological study of language.

[1] I agree with Chomsky that it is "a curiosity of our intellectual history that cognitive structures developed by the mind are generally regarded and studied very differently from physical structures developed by the body" [3, p. 37]; a peculiar form of methodological mind/body dualism [4, "Replies" to Lycan and Poland].

[2] Notice, incidentally, that this conception also renders any synchronic/diachronic dichotomy incoherent: all there is in the world are individual speakers with individual internal linguistic systems, some of them overlapping with regard to parameter settings. Since there is no speaker-independent notion of language, there is no "English", "Japanese", "language change", etc., in the strict sense.

We know that the essence of our linguistic abilities is a combinatorial system that arranges atomic symbols into structured syntactic representations. The autonomy and primacy of this core language engine was demonstrated by Chomsky fifty years ago: *Colorless green ideas sleep furiously*—a perfectly meaningless sentence, the syntax of which we nevertheless immediately perceive as well-formed [13, p. 15]. By virtue of computing structures in a recursive fashion, the combinatorial system that arranges words into complex structures is unbounded, i.e. it yields an infinite array of structures that can be put to use. This is the individual speaker's internal linguistic system, part of his or her biological constituency.

Language can be used in several ways. In inner speech, it is put to use in the sense that it expresses thought, but not phonetically—linguistic structures are interpreted by our conceptual apparatus. In the case of normal language use, these structures are externalized by a complex interplay of sensorimotor components; the result is signs or speech. Notice that externalization is in this sense peripheral: it is no more than an optional, modality-dependent way of expressing the internal structures that core grammar provides. FLB, the Language Faculty conceived in a broad sense, comprises the computational syntax system as well as the systems active in linguistic performance, conceptual apparatus and sensorimotor systems.

The recursive core of grammar, call it narrow syntax, is part of what Hauser, Chomsky and Fitch label FLN. But there must be something else: FLN must *interface* with performance systems in order to allow usage of the structures it generates. So in addition to narrow syntax, there must be mapping procedures that feed the outside systems of thought and articulation to meet their respective conditions—traditionally, these mapping components are called semantics and phonology. Since we are able to use language, it must be the case that at least a subset of the structures provided by FLN satisfy legibility conditions of the outside systems.[3]

The picture that Hauser, Chomsky and Fitch offer is that of 'blind' recursive generation, coupled with interface components that transform the output of narrow syntax into representations encoding sound and meaning, and a range of modalities of performance, oral speech being one of them, that lie outside the narrow-syntactic system. These modalities are, crucially, distinct from the abstract capacity FLN, but interface with it. Hauser, Chomsky and Fitch offer a range of evidence, corroborated in later studies [14, 15], suggesting that these performative components—conceptual-intentional and sensorimotor systems—are present in other species, such as higher primates—a conjecture that goes back to Descartes. Hence, performance systems, while recruited for language, cannot give rise to the crucial properties that account for the unique status of human language: recursive syntax and interface mappings, or FLN for short.

These findings set rather narrow boundaries for theories of language evolution. First, if Hauser, Chomsky and Fitch are correct, then FLN must have evolved when performance systems were already in place. If the outside systems of FLB are present in other species, these systems cannot have 'evolved for' human language, and they cannot account for its structural properties; rather, the fundamental novelty of the Language Faculty is the mediation of a recursive syntax between both systems.

[3] In fact, there is good reason to assume that only a subset is usable: see note 10 below.

Second, if FLN evolved only in humans, this suggests that its evolutionary history is rather short [16, 17, 11]. Indeed, there is evidence that language arose in the species about 100,000 to 40,000 years ago, the latter date usually associated with the so-called Upper Paleolithic Revolution. The fossil record suggests that a sudden proliferation of art, personal ornaments, tools, burials and other forms of complex social organization and planning took place at this time, often taken to be the first clear indications of the existence of language and symbolic thought. In the light of this evidence, Stanford archeologist Richard Klein assumes that it was a "fortuitous mutation" that "promoted the modern capacity" for language, triggering a "sudden and fundamental" change [18, p. 1457]. If language is indeed a product of the Upper Paleolithic Revolution, it evolved virtually yesterday.

The recent paradigm shift in evolutionary biology, commonly labelled the Evo-Devo revolution, has given credibility to claims of saltational emergence of a trait, triggered by some miniscule mutation, or as a by-product of a functionally unrelated change, such as simple brain growth [19, 20, 21, 22].

It is hard to see how this evolutionary story could account for a richly structured FLN of the kind assumed in earlier theories couched in the Principles and Parameters framework. A standard textbook of syntactic theory contains chapters on a phrase-structure module, a Case module, a theta module, a Control module, a binding module, and other subcomponents governing the workings of FLN [5, 23]. These modules and principles interact in an intricate fashion to yield outputs of a certain degree of well-formedness: for instance, *John loves Mary* is a fine sentence of English, while **loves Mary* is a violation of the Theta Criterion. If the structure of UG is indeed highly complex, composed of a range of different subcomponents, its evolutionary origin is entirely obscure. In fact, this criticism was put forward by Jean Piaget in the aforementioned 1974 debate, who took the emergence of an innate UG to be "biologically inexplicable" [24, p. 31].

The objection is legitimate. The enrichtment of the internal program of UG yields an object too complex to withstand the minimalist *why*-question: why is the structure of FLN this way, and no other? From an evolutionary perspective, it seems more reasonable to "approach UG from below", as Chomsky explicitly proposes [25]: how little can we attribute to the genetic endowment while maintaining explanatory adequacy?

To a good approximation, the internal structure of the language organ is determined by four factors [26]. The first factor is the genetic endowment (= UG), expressed in the initial state of the Language Faculty. The second factor is external linguistic data, which shapes the development of the language organ within narrow boundaries [27]. The third factor comprises what is called "developmental constraints" in theoretical biology—general principles of biophysics [28, 19, 29]. The fourth factor concerns the embedding of the Language Faculty within the mind—that is, the way it interfaces with other components. It should be obvious that the evolutionary story just sketched emphasizes the role of the epigenetic third and fourth factors: developmental constraints and architectural considerations concerning the interfaces between core grammar and outside systems. Could it be the case that it is these factors, rather than the genetic endowment, that account for much of the complexity of natural language?

In fact, the suggestion that Hauser, Chomsky and Fitch derive from their findings is that "Many of the details of language ... may represent by-products of [FLN], gener-

ated automatically by neural/computational constraints and the structure of FLB." Their suspicion is that the development of the Language Faculty is crucially "constrained by biophysical, developmental, and computational factors shared with other vertebrates. ... [S]tructural details of FLN may result from such preexisting constraints, rather than from direct shaping by natural selection targeted specifically at communication." As they rightly note, as far as this proves to be the case, the mechanisms internal to the Language Faculty "are not, strictly speaking, adaptations at all" [12, p. 1574]. This is the basis for the *Strong Minimalist Thesis* (SMT): Language, FLN, is an optimal solution to the minimal design specifications of the interfacing systems [30, 31, 32, 16, 25].

The notion of optimality of language is often flatly rejected as a ridiculous, outlandish thesis. In most cases, this hostility turns out to be based on a conflation of two distinct notions of optimality: functional and structural optimality. In fact, many opponents of Hauser, Chomsky and Fitch's thesis of language as an exaptation—a by-product, as opposed to an adaptation—claim that since language is a communication system that provides advantages for the organism, the ultimate explanation of its internal structure must be natural selection. In this view, what we expect to find is a gradual evolution of the language organ, optimizing it for purposes of communication [33, 34].

But a closer look immediately reveals that language is far from optimal in this sense; in fact, it turns out that the use of language for communicative purposes is no more than an epiphenomenon of the workings of the system. Let me just point out three elementary observations. First, central properties of human language, such as recursive embedding and dislocation (creating gaps in surface structure) *hinder* communication, creating considerable memory and parsing problems.[4] In this case and many others, it can be shown that language performance employs various strategies to circumvent the problems created by FLN, and how it systematically avoids the multitude of well-formed but unusable structures it provides.[5]

Second, if language were indeed an adaptation to communicative pressures, it is unexpected that the system is underspecified (parametrized), yielding a variety of superficially diverse languages. An efficient communication system would attain a fixed stable state, to ensure universal intelligibility. In fact, as Cedric Boeckx (p.c.) points out, parametric variation quite often creates obstacles for performances, as in the case of head-directionality. In head-final languages such as Japanese, heads appear late in linear order, creating significant parsing problems. A functionalist view is forced to assume the rapid extinction of this language type, contrary to fact.

Finally, a need to communicate does not explain why we use language for this task instead of some other medium—e.g., chemicals (like ants) or a dance (like bees). Minimalist *why*-questions arise inevitably: why is human language the way it is?

[4] Center embedding does not alter the transparent well-formedness of the structure, but it makes it pretty much unusable:

(1) The cat [the dog [the cow [the man milked] kicked] chased] left

It is hard to see for any attested property of language structure what communicative function it could fulfil, if the term makes any sense at all. What is the communicative advantage of binary and endocentric phrase structure, hierarchical syntax, successive cyclic movement, etc., over other logical possibilities [35]? Further examples are semantic properties such as conservativity of quantifiers, again without any clear correlate in terms of communicative efficiency [36].

[5] Resumptive pronouns are but one possible example [37].

What is more, for a system designed for "communication", we expect a rather tight correlation between form and function; ideally, there should be a one-to-one mapping between communicative intention and expression. In natural language, however, the opposite is the case. One proposition can be mapped onto several forms, such as an active and a passive sentence. Even worse, one form can have different interpretations, creating one of the most notorious properties of language: ambiguity. All this suggests that the function of language is "imprisoned" by the dictate of form—a typical feature of an exaptation [38]. It is, therefore, unlikely that communicative function could play any causal or explanatory role in a true theory of FLN. Geoffroy de St. Hilaire's formalist tenet seems appropriate: "Such the organ, such will be its function"—and not vice versa [20, p. 304].

Consequently, the notion of optimality that is at stake in the Minimalist Program is not some kind of functional optimality.[6] What is claimed to be optimal are the internal mechanisms of FLN, the abstract system that accounts for our linguistic competence. It is an entirely distinct question how this competence is put to use, and how optimal the strategies of the performance systems are. It is the underlying nature of the system, distorted by performance factors in its actual expression, that SMT is concerned with.

None of the evidence—theoretical, biological or archaeological—is conclusive. But the question of language design is intimately tied to the Minimalist Program and its characteristic why-questions. Returning to the four factors, it is obvious that Hauser, Chomsky and Fitch's story emphasizes the role of the third and the fourth factors: developmental and architectural constraints, respectively. Thus, the explanatory burden is shifted from UG, the internal program, to more general (and mostly unknown) principles of biophysics and "mind design:" if a property of a system follows from natural law and other externally imposed "design" principles, we do not expect this property to be encoded in the genome. Many natural phenomena exhibit a high degree of design and optimality by virtue of their third and fourth factor properties alone, without being controlled by any internal program.[7]

If, as it seems, FLN is not a trait functionally adapted to specific communicative needs, and given the assumption that it evolved recently in the species, without any similar system found in other species, the conclusion seems to be that the core linguistic system, FLN, evolved under natural constraints of physical law and embedding in the brain as a product of some rewiring of neural circuits. This, in turn, suggests that FLN might indeed be an optimal system in that it is not shaped by gradual evolutionary tinkering, but a fairly simple product of natural law and organizational principles. We therefore expect its computational capacities to be characterized by natural properties of complex systems, such as efficient computation and minimization of memory load, yielding an optimal solution to the problem of linking the interfacing performance systems. In essence, the minimalist bet is that efficient computation is a natural law—

[6] Consequently, the minimalist *why*-questions are profoundly different from *why*-questions that arise in the analysis of systems engineered for an external purpose or function. A question of the latter kind might be, "Why does formal language L use the symbol $\forall$?" In the domain of biology, the essential *why*-question is "why such large empty spaces exist in conceivable, and not obviously malfunctional, regions of potential morphospace" [20, p. 347].

[7] Stock examples are cell division, virus shells, pattern formation in plant and animal morphology, crystal growth, snowflakes, etc. [39, 21, 22, 40, 41].

the Galilean faith in the optimality of nature, an idea that has a "distinguished tradition" in natural science [29].[8]

FLN is the linking solution to design specifications imposed by interfacing non-linguistic mental systems that linguistic theory seeks to reverse-engineer, remaining agnostic about use and function, which make no prediction on the structural properties of grammar.[9] Chris Cherniak has argued that the brain structure of simple organisms he investigated is an optimal solution in this sense, without any recourse to a naïve notion of "function". He writes, "When mechanisms are explored by which [optimal wiring in nervous systems] is attained, significant instances turn out to emerge 'for free, directly from physics': In such cases, generation of optimal brain structure appears to arise simply by exploiting basic physical processes, without need for intervention of genes" [45, p. 103]. Consequently, Cherniak describes the phenomenon as an instance of "non-genomic nativism". In the case of language, perhaps UG contains little more than the instruction for recursive Merge.[10]

Let me briefly illustrate the logic of minimalist reduction by the example of phrase structure. Earlier theories within the Principles and Parameters framework assumed that there was a distinct phrase-structure component yielding the input to transformations; in fact, it was assumed that the initial generation of a phrase marker constitutes an independent computational cycle. Assume, instead, that an organism is endowed with a mental capacity to merge lexical elements, that is, to take two lexical elements and put them together to create a new, complex, syntactic object. Since Merge is recursive, this syntactic object can in turn be merged with some other object. In this way, Merge yields hierarchical phrase structure: once Merge is assumed as part of UG, hierarchy comes 'for free'. What is more, Merge yields both base Merge, corresponding to argument structure, and target Merge, corresponding to 'dislocation'—the latter a descriptive term, not a grammatical operation. Both come 'for free', hence we expect the system to make use of both.

At this point, speculations concerning language evolution become highly relevant for linguistic theory. Assume that SMT holds: FLN does not mediate between sound and meaning systems in some random way, but it does so in an optimal way. In that case, we expect it to obey natural principles of efficiency. For example, Merge does not alter the structures created thus far; it will always apply to the root of the syntactic tree, leaving everything else untouched. From this view of Merge, it follows that displaced elements are nothing but sets of occurrences, occupying distinct positions in the tree. So-called "reconstruction effects" follow: an element can be pronounced in a displaced

[8] Notice that the minimalist approach to FLN is not merely methodological, in the spirit of Occam's Razor, but rather ontological: "Beyond Occam ... is the metaphysical supposition that nature itself operates on principles of bare necessity, whenever it can get away with it" [29, p. 58].

[9] Evidently, this internalist conception of reverse-engineering in cognitive science is fundamentally opposed to the Neo-Darwinian position, which holds that "in reverse-engineering, one figures out what a machine was designed to do," a task that becomes feasible "only when one has a hint of what the device was designed to accomplish" [42, pp. 21, 42]. The approach is—at best—highly dubious [43, 29]. By contrast, minimalist reverse-engineering is entirely I(nternal)-functionalist [44].

[10] There is good reason to believe that UG does not contain any language-specific principles at all, at least if the evolutionary picture assumed here is on the right track. If FLN emerged more or less saltationally, it would indeed be highly surprising if it would satisfy all legibility conditions of the interfaces and not yield any output that is illegible. What the approach suggests, rather, is that FLN is a highly general recursive function without specific constraints, and that complexity arises only at the interfaces.

position but still be 'visible' to the system in its original Merge position [46].[11]

The simple operation Merge, following natural principles of optimality, can thus account for a variety of core computational properties of language, obviating the need for dedicated subcomponents and principles specific to FLN. If linguistic theory succeeds in reducing the superficial complexity of language to natural principles of optimality in this fashion, attributing only the residue to UG, the theory has reached the (arguably) deepest level of adequacy: it has answered the question *why* language is the way it is.

While parametrization is not what we expect from a "communication" system, it is what we do expect if SMT holds and the genetic endowment is minimal.[12] It is a truism that, as biologist Adrian Woolfson puts it, "the structural information content of genes is considerably less than that of the systems they encode"; rather than specifying the system's structural information as a whole, "genes encode a far more economical representation of this information that incorporates only the essential aspects necessary for recreating the system" [47, p. 266]. This is precisely what a minimalist conception of the Principles and Parameters model attempts to show for the domain of language; perhaps UG contains little more than the instruction for recursive Merge, obviating the need for "biologically inexplicable" intricacies specific to FLN entirely. The Minimalist Program follows Piaget in this respect.

Instead of taking the risk of constructing an arbitrary pseudo-theory that accumulates artificial principles to achieve maximal data coverage, linguists should recognize that "the search for general patterns is fundamental to science and is not easily suppressed, even when the relevant data set looks very complex," as it does in case of virtually every natural system (biologist Wallace Arthur [19, p. 757]). And some plausible computational patterns of language have been uncovered [48, 25, 49, 50, 51, 52].[13]

As we experience in our everyday lives, language is a highly useful ability, despite the properties that I mentioned earlier that indicate that communication is really an epiphenomenon of the underlying system. Nobody denies the usefulness of language, but, as mathematician-biologist Peter Saunders puts it, summarizing pioneering work in theoretical biology, we have to recognize that "Not everything that is to our advantage is the product of selection. It may just be how things naturally are" [54, p. 373]. The goal of the internalist reverse-engineering project—based on the four factors, not some misleading notion of external "function"—is to show that this is true for the biological object language, understood in the sense of FLN. After the nativists's successful elimination of the external program as conceived by Piaget as a substantial factor in the design of language, the prospects of a non-genomic nativist account of the

[11] Notice that usually, only one occurrence of a dislocated element is pronounced, while all other occurrences are deleted in the phonological component—another striking example for the communicative inefficiency of FLN, given that realization of all copies would simplify parsing considerably.

[12] Moreover, given the universality of semantics and the special status of externalization, we expect parameters to affect the workings of the phonological component only, in the best case. Variation with regard to word order, for example, is expected for a system optimized for the computation of C–I representations, where word order does not matter. It SMT follows from SMT that parametrization is not arbitrary but optimal in this way.

[13] For language, the most striking imperfections challenging SMT (at least *prima facie*) are related to morpho-phonology. Other than in artificial languages, which do not have any allomorphy, identical morphemes in natural language can appear in different shapes, often without any semantic reflex. Presumably this should not come as a surprise, given the ancillary status of the phonological component in general [53, 25].

biology of syntax, or something close enough, opens the door to the elimination of the internal program as well.[14] For the cognitive science of language, this would be a most welcome result.

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[14] There is a salient parallel between both enterprises. A view of the Language Faculty as shaped by natural selection effectively amounts to ascribing its internal structure to external forces, the relation between both being largely mysterious and explanatorily empty, if not incoherent. The constructivist finds himself in a very similar situation. It is only superficially a paradox that virtually the same arguments that were put forth in favor of the elimination of the external program can be used to argue for the elimination of the internal program.

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