LANGUAGE PHYLOGENY AND THE EVOLUTION OF SEMANTIC COMPLEXITY

Filogenia da Linguagem e a Evolução da Complexidade Semântica

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INTRODUCTION

Questions concerning the evolutionary origin of human language are now the focus of a rapidly growing and systematic body of research (e.g., Pinker (1994), Christiansen; Kirby (2003), Hurford, Studdert-Kennedy; Knight (1998), Nowak; Krakauer (1999), Calvin; Bickerton (2000), *inter allia*). Although neuroscientists, philosophers and anthropologists have been interested on the topic for slightly different reasons, from the point of view of modern linguistic theory, the emergence of 'evolutionary linguistics' is the ultimate implication of a 50 years old research program that strives to build a coherent picture of the linguistic capacity of *Homo sapiens* within a broader understanding of human cognition and behavior (Chomsky (1965, 2001), Pinker; Bloom (1990), Hauser; Chomsky; Fitch (2002)).

In this work we offer a model on the evolution of a particular piece of natural languages grammars that shows, among other things, how a cooperative effort between evolutionary linguistics and semantic theory may be directly illuminating to the field. This necessary cross-talk between semantic theory and evolutionary linguistics has lagged behind in relation to

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equivalent applications for other sub-disciplines of linguistics, such as phonology and syntax (cf. Hurford; Studdert-Kennedy; Knight (1998)). The work is embedded, in both methodology and substance, within a theoretical framework for Evolutionary Linguistics currently under development (Carvalho (2005), Carvalho (submitted), Carvalho (in prep.)).

SOME BACKGROUND ON EVOLUTIONARY THEORY

As the central source of theoretical integration for the biological sciences (Dobzhansky et al. (1977)), Evolutionary Theory furnishes a rationale for the pursuit of many kinds of questions: one may be interested on the evolutionary interpretation of the fossil record (Simpson (1944)), on the mechanisms of inheritance and replication (Dawkins (1976), Williams (1975)) or on the emergence and maintenance of complex adaptive structures (Dawkins (1983), Maynard Smith (1969)).

As I argue elsewhere (Carvalho (in prep.)), evolutionary linguistics (and maybe, theories about the evolution of cognition in general) should concentrate on the construction of hypothesis concerning the phylogenetic distribution of cognitive traits involved in linguistic behavior, which implies also hypothesis on putative character-state transitions, their characteristics in ancestral stages as well as a primary role for comparative data and criteria for hypothesis-choice.[1,2] Granting that this is not the correct place for the justification of this position, some remarks are nonetheless necessary.

Within the primarily historical approach to phylogenetic reconstruction (Kemp (1985), Kluge (1999)) two complementary but independent ways to approach the problem are usually described (cf. Lauder (1982), Desutter-Grandcolas et al. (2003), O'Hara (1988)): on one hand, the researcher may focus its study on the chronicle of the character-state transitions that occurred during the process of phylogenetic descent under scrutiny, on the other he may suggest hypothesis on the scenario of evolutionary forces and processes that caused the character transformations to come about and ultimately promoted their fixation or maintenance within particular populations. This division of labor for evolutionary studies has also been success-

[1] Another useful consequence of this program is that the use of phylogenetic reconstruction models forces the language evolution researcher to spell-out clearly its background assumptions on the nature of evolutionary processes (Kemp (1985)), a situation that is obviously at variance with the current standards of inquiry in the field.

[2] This approach differs markedly, but is complementary to, the standard approach within evolutionary psychology (cf. Tooby; Cosmides (1989)).

fully applied to the study of the evolution of hominid and primate social behavior (Foley; Lee (1989)) and has been seen as a topic of major relevance for the social sciences (Boyd et al. (1997)).

The first approach is deeply related to some central topics currently under debate within Evolutionary Theory, such as the nature of the "phenotypic space" of possible characters, the role of constraints and the issue of complexity in evolution (Kauffman (1993), Lauder (1982), McShea (1991)). It is exactly this question that will be addressed by the present work in a more direct fashion. Even tough the other, "functional" question, is clearly the central concern of any evolutionary study (Mayr (1961)), it will be discussed without deeper considerations in the final section.

1 GRAMMARS AND THEIR (LONG) HISTORY

Along with some recent trends in Linguistic Theory (Chomsky (1995), Kean (2003)) we will accept, as a minimal specification for natural languages grammars, a definite relation *R(S, P)* holding between "sound" (here, *P*) and "meaning" (here, *S*). Although obviously simplistic, models of this kind have also been useful in Learnability Theory (Wexler; Culicover (1980)) as well as in Evolutionary Theory (Boyd; Richerson (1985)), when empirical faithfulness may be relaxed if some improvement in comprehension is achieved. Beyond this gross statement, we can further specify our model in the following directions: (1) the set *P* stands actually for some non-empty set of "units of implementation", not necessarily of an acoustic-vocal modality; (2) *S* stands for a non-empty set of "information" units coded in the signals used for communication; specifically, it denotes information in a sense closer to "meaning" or "representations" (intentions) and not information in the technical sense of the mathematical theory of information, quantified as "ambiguity" decrease. And finally (3) we define *R (S, P)* as a very specific kind of relation, namely a bijective function. This means that *R(S, P)* defines a set *S x P* (a cartesian product), such that $S\ x\ P = \{<x_i , y_i> / x_i\ S , y_i\ P\}$. This much said, our preliminary relation *R(S, P)* may stand for an arbitrary set of signals employed for communication.

Before moving ahead, a comment is needed. One may wonder what does it mean to say that a sound-meaning pairing relation is the "minimal specification" for a grammar or an intentional communication device of a different sort. I will assume the position, accepted among generative linguists since the demise of the Derivational Theory of Complexity, that linguists are working at a level of analysis similar to the level proposed by

David Marr (1982) to the task of describing cognitive agents as information-processing mechanisms where the function or problem to be computed is specified (cf. Berwick; Weinberg (1984)). Then, to say that some particular object or property is part of this "minimal" specification might mean that any of the possible algorithmic ("low-level") approaches to the computational problem will need to instantiate or represent it. In the case of natural language, the existence of apparently misplaced elements heading chains derived through movement is a strong candidate for the status of one such "minimal" element (Pesetsky (1997)).

As its stands, it is obvious that in order for the definition of our putative pre-grammatical system of communication to work, we need the domain set, S, to be "equinumerous" to the range set P. That is, it should be the case that $|S| = |P|$. Assuming however that S grows too large, there is a way to bring order to our system. In terms of a set of signals used for communication, "order" could mean what Optimality-Theoretic systems for syntax call 'interpretability' (Pesetsky (1997)): all the semantic signals (members of S) should find some way to be coded into the "interface" code of the implementing system (members of P). The way whereby this kind of interpretation demand may be fulfilled is through the action of a simple combinatorial principle called "the Pigeonhole Principle": in intuitive terms it states that whenever you have $n+1$ pigeons trying to match into n pigeonholes then it is the case that some pigeonhole will house more than one pigeon. In more formal terms, it means that formal objects like $< x_1 , x_{i.} ... x_n ; y_i >$, for $x_i \in S$ and $y_i \in P$ are now allowed within the set of objects defined by our function $R\ (S, P)$. As it turns out, this kind of object, allowing for many-to-one mappings of meaning units into implementing units, is exactly the sort of object that results from the application of morphological principles forcing (lexically) distinct bundle of features to cluster (e.g., Harley; Noyer (1999), Embick; Noyer (2001)). As a final note, the application of the Pigeonhole Principle is theoretically coherent with our assumption, made explicit in the previous paragraph, about which level of analysis we are working at, given that the principle in itself *does not* provides an algorithm to find the complex objects that it allows for, it only states that such objects exist (cf. Brualdi (1998)).

I would like to insist in the point, denied by some commentators of earlier drafts of this paper, that the above mentioned (cf. Abstract) convergence of results does not trivialize the model here presented. Indeed, not only Game Theoretic models of language evolution, but also some studies on the ontogeny of language, seem to suggest a "critical mass" scenario (e.g. Marchman; Bates (1994)), where an enlargement in the number of independent signals ("words") may lead to dramatic reorganizations of our system, maybe converging on the appearance of grammar-like patterns, such as clustering or concatenation. Nevertheless, to say that there are "trivializing" implications between these results really ignores all the fun about these hypotheses. The present work was founded upon the analysis of possible chains of "character states" whereby a small part of the human language faculty may have passed during its evolution. It is mainly a talk about phenotypes and the relevant phenotypic space to represent different character states or taxa in a phylogenetic analysis. This result was held to be significant for the continuity/discontinuity debate because most of the alternative accounts of language evolution that argued for discontinuity did so on the basis that they could not conceive of a gradual transition from whatever you may consider an "ancestral communication system" to language, through a series of functional states (e.g. Bickerton (1990)). This kind of result, significantly modest from the perspective of an ideal and exhaustive account of the phylogenetic origins of language, cannot tell under which conditions this "grammar like" device of communication would be an "unbeatable strategy" for a population of speakers, whether there are many different such strategies or whether there is none. This is the task of Evolutionary Game Theory. In a classic text of the field, John Maynard Smith (1982) notes how these two approaches have been largely independently carried by researchers:

> ... In practice, too much effort is put into seeking an optimum and not enough into defining the phenotype set. In the Hawk-Dove Game, for example, considerable sophistication has been devoted in analysing the game, but the strategy set is ridiculously naïve. (...) My reply to this complaint would be that it wrongly identifies the purpose of the Hawk-Dove Game, which is not to represent any specific animal example, but to reveal the logical possibilities (for example, the likelihood of mixed strategies) inherent in all contest situations. *When confronted with specific cases, much more care must be taken in establishing the strategy set*. (p. 5-6, Italics mine).

The quotation above demonstrates not only the complementary roles played by evolutionary game theory and by the creation of hypothesis concerning character states and their interrelations, but also shows how the latter can inform the former. In special, the present work is about not being "ridiculously naïve" about the relevant phenotypes.

2 Meaning meets the Natural World

We can now present some hypothesis, available in the literature on language evolution, that may possibly account for this enrichment of semantic representations, that in turn, following our scenario above described, might have lead to some crucial reorganizations in some putative ancestral communication device.

First of all, it is interesting to observe how the approach described in this paper seems to be reasonable from the point of view of phylogenetic analysis. As we try to account for some of the descriptions of the communication repertoires of non-human primates, we can see that the application of the Pigeonhole Principle is subject to functional constraints ("communicative functions") and isn't in any sense a necessary outcome of an increase in semantic complexity. Some well-described primate species, such as the Gelada (*Cercopithecus aethiops*) or some species of baboons (*Papio cynocephalus ursinus*) show a striking asymmetry: on the one hand they show amazingly complex cognitive capacities to represent and manipulate information concerning features of their social world (e.g., third-party relations; kinship/status ranking of different individuals) but nonetheless, not even a small fraction of this complex knowledge network is actualized in their (rich) system of vocal communication (cf. Cheney; Seyfarth (1990), Seyfarth; Cheney; Bergman (2005)). The burden of the research could then be focused on the specification of the adaptive problems and selective pressures that, in our lineage, effected that contingent transition and caused the spread and improvement of communication devices with semi-grammatical routines at the expense of simpler one that consisted in little more than sets of independent signals, as presented in the previous section.

From this perspective we can start from the observation that many researchers have pursuit the idea that many of the unique intellectual and behavioral capacities of primates, as well as their high levels of encephalization, may be due to strong adaptive pressures for cognitive processes related to "social navigation" (Humphrey (1976)). The different incarnations of this proposal have been diversely labeled, such as "the social brain hypothesis" (Dunbar (2003)) or the "Machiavellian intelligence hypothesis" (Byrne; Whiten (1988)) but the rationale behind them is the same. Relative to the representational capacities underlying language, Robert Worden (1998) proposed that the hierarchical organization of syntactic-semantic knowledge in natural languages furnishes a direct testimonial to the representational basis of social knowledge from which it was co-opted during evolution. Worden uses a single formal apparatus to describe the primate-typical social knowledge database and to represent small pieces of natural language semantics (fig.1).This kind of "script" representation is extremely popular in AI knowledge engineering:

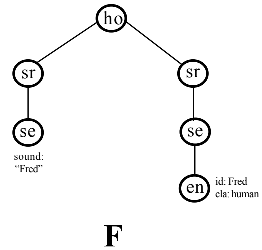

Fig.1. A script in Robert Worden's notation for representing primate social knowledge networks and (possibly) syntactic-semantic knowledge too.

One of the striking implications of work under the aegis of the "social brain hypothesis" is that it also calls for an integration of semantic theories with non-linguistic domains of representation. Under this perspective, psycholinguistic work such as those developed by Ray Jackendoff, Leonard Talmy and Steven Pinker are really welcomed in this integrative effort (e.g., Jackendoff (1983)).Together with the growing interest in 'cognitive ethology' approaches to the study of animal behavior (Griffin (1992)) this promising line of research is suggesting that many of the cognitive underpinnings for linguistic behavior are actually quite ancestral traits, and not the result of unique events and contingencies of our recent hominid history (cf. Marcus (2004)).

Alex Martin's work on visual imagery and higher level visual processing as representations co-opted to language during evolution offers another promising line of research on the role of semantics in understanding language evolution (e.g., Martin (1998)). The idea relies on the existence of uniquely primate temporal lobe regions (Sanides (1975) that support the processing of object-related features as well as their matching with previous experienced stimuli. The relation with language is established by the huge amount of evidence (cf. Damasio (1990), Usui et al.(2003), Hickok; Poeppel (2004)) pointing to the fact that the temporal lobe homologues in humans act in the storage of semantic representations and play some role too in their conversion into phonological information.

This last section of our presentation sketches some lines of research that are, in our opinion, highly promising to the task of unraveling the adaptive nature of language and its phylogenetic status. The so-called "social brain hypothesis" furnishes a powerful research program and theoretical integrative force for a range of disciplines, from primatology and paleoanthropology to evolutionary psychology and neuroscience. Studies on the representation of knowledge in primate brains lends support to the hypothesis that higher-level visual areas (mainly those concerned with object recognition in posterior temporal areas) and higher level sensory cortices related to socially significant tasks such as individual recognition, could have been co-opted as storage sites for semantic features assembled to form lexical items (Martin (1998), Pulvermuller (2003)) As we argue elsewhere, (Carvalho (in prep.)) the other approaches that emphasize both comparative as well as neuroscientific data should be taken seriously as a way to constrain the densely populated space of hypothesis that abound in the field of 'evolutionary linguistics'.

3 Summary and Conclusion

In this work we presented some work in progress concerning a specific hypothesis, as well as a particular research program that legitimates it, within the rapidly growing field of approaches to the evolutionary characterization of our language faculty. The hypothesis is acknowledged as being still in an undesirable form relative to an ideal framing (i.e., neuroscientific or neurocomputational) that, in our view, maximizes the fruitfulness of traditional phylogenetic approaches. In particular, the framing of the functional hypothesis here sketched in terms of a full-fledged processing theory (e.g., Anderson's ACT-R (Anderson et al. (2004)) should make possible the establishment of a number of processing constraints (e.g., working-memory loads, list- and frequency-effects on particular lexical items) that, taken as background assumptions on the system's efficiency, could (or not) select for the reorganization that we propose in this paper (i.e., the use of the Pigeonhole Principle) as an optimal solution for the system that deviates from simple bijectivity between signal and meaning units. If our proposed strategy in no way follows from independently motivated constraints under some criteria of optimality, then the hypothesis may be doubted. In this way, and contrary to some comments of referees on drafts of this paper, the hypothesis is actually testable, but only with some utterly necessary auxiliary hypothesis. These qualifications are in harmony with our observations on the allocation of the present work within Marr's research strategy for the analysis of cognitive agents (cf. section 1), as questions of efficiency, resource allocation and so on are posed at a lower level of algorithmic specification.

Some of the most significant aspects of our hypothesis deal with the role that semantic theory, among all subfields of linguistics, might play in a coherent and exhaustive evolutionary linguistics. Although our semi-formal model focuses on a rather simplistic notion of semantic complexity, assessed by the size of set S, it may, nevertheless, prompt the hypothesis to some low-level description in computational terms. These aspects are highlighted by pointing out the relevance of independently motivated hypothesis and approaches in bringing about this absolutely demanding and rich theoretical contact, as exemplified by the putative relations between the semantic substrate of language and general cognitive and perceptual adaptations of the primate order.

ABSTRACT

This paper addresses one specific hypothesis on the phylogeny of the human language faculty where semantic theory might play a central role. It is shown how an increase in semantic complexity within a hypothesized communication device may lead, through the action of a single combinatorial principle, to the emergence of a set of well-known grammatical representations afforded by UG, namely, a mapping relation including morphological subroutines. Comparative data from non-human primate cognition is taken into account and a sketch of the possible functional forces behind the transition from morphology-less grammars is examined. The hypothesis presented converges with independent work on language ontogeny (e.g., MARCHMAN; BATES (1994), PLUNKETT; MARCHMAN (1993)) as well as with results from game-theoretic approaches to language evolution (NOWAK; KRAKAUER (1999), NOWAK; PLOTKIN; JANSEN (2000)). Besides this striking result, a strong connection with Linguistic Theory and the rest of Cognitive Science is enforced, a state of affairs not easily found in the general literature on the evolution of language.

Key-words: *language evolution; semantic theory; grammar-cognition interfaces.*

RESUMO

O presente trabalho examina uma hipótese particular acerca da caracterização evolucionária da faculdade humana de linguagem em que a teoria semântica pode ter um papel crucial.

Mostra-se, em particular, como o aumento na complexidade de um mecanismo hipotético de comunicação pode levar, através da ação de um princípio combinatório simples, a emergência de um conjunto específico de representações fornecido pela GU, permitindo a presença de mapeamentos capazes de definir rotinas morfológicas. Dados comparativos relativos à cognição de primatas não-humanos são levados em consideração, assim como algumas hipóteses acerca das forças funcionais por trás das transições a partir de mecanismos nos quais as representações morfológicas estejam ausentes, são examinados. A hipótese articulada converge com uma série de trabalhos sobre a ontogênese da linguagem (e.g., MARCHMAN; BATES (1994), PLUNKETT; MARCHMAN (1993)) e com resultados advindos da Teoria dos Jogos (NOWAK; KRAKAUER (1999), NOWAK; PLOTKIN; JANSEN (2000)). Além desse resultado significativo (que insistimos como não sendo de modo algum trivial) uma ligação forte com a Teoria Lingüística e com as Ciências Cognitivas é reforçada, uma situação que nem sempre é contemplada na literatura sobre a evolução filogenética da linguagem.

Palavras-chave: *evolução da linguagem; teoria semântica; interfaces cognição-gramática.*

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