Neandertals. Per què podrien haver parlat i per què no?

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A na Sílvia,
A n'Ariadna.

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RECURSION, DUALITY AND VOCAL SYSTEM:

ASSESSING THE MARKS OF LANGUAGE AS A *H. SAPIENS'* SPECIFIC FACULTY

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Recursion, duality and vocal system: assessing the marks of language as a *H. sapiens'* specific faculty

PREFACE

Agraïments. Acknowledgements

Tota obra té un inici i un final i tanmateix, n'hi ha que no arriben a la darrera estació. Aquesta tesi doctoral ha pogut arribar a bon port després d'una travessia no exempta d'avatars, aventures i problemes. Altrament, segurament no hauria estat tan interessant, ni el creixement personal tan alt.

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Però ni tan sols aquest valuós suport no hauria estat prou sense les dues persones que avui ocupen el meu cor, la meva vida: la meva estimadíssima Sílvia i la nostra meravellosa filla Ariadna. Els moments més durs de tot aquest procés han estat per na Sílvia, que amatent i pacient m'ha ajudat, ha escoltat les meves conferències, les meves idees, esbojarrades més d'una. Ha estat capaç d'aguantar durant anys que la seva parella fos als niguls, pensant com era que aquelles mones tenen aquells crits d'alarma, o com és que la tecnologia Neandertal no va anar més enllà del que s'ha trobat fins ara. Fins i tot va venir a visitar-me a Leipzig, al Max Planck, i va sobreviure a una colla de joves entusiasmats amb l'estudi dels primats que no feien altra cosa que parlotejar fora aturar sobre el mateix tema una vegada i un altra. En canvi, la meva filla Ariadna, l'alegria permanent de ca nostra, ha superat la generació anterior, i fa bé en no escoltar les cabòries de son pare, presentant-me una rialla i una de les seves juguetes cada vegada que se m'ocorre de fer-li un comentari. I és que ella de manera ben natural m'assenyala allò que realment té interès. Quina saviesa, la seva. Me deman on és que la vaig perdre. A elles dues, els agraesc de ser-hi cada dia amb jo.

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també l'actitud sincera i humil envers l'estudi científic.

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Resum

En aquest treball es parlarà del llenguatge amb un enfocament biolingüístic; és a dir, que s'investiga part dels aspectes biològics que efecten el llenguatge, i també aquells factors físics que poden afectar la seva estructura biològica.

La primera part és una introducció en la qual present la meva idea de la biolingüística i el llenguatge, relacionats ambdós amb els estudis sobre evolució. Destac que fins ara la lingüística ha presuposat que el llenguatge era cosa només de la nostra espècie, però que els recents treballs en genètica provant diferents casos d'hibridació posen una ombra de dubte en aquestes assumpcions.

A la segona part, faig una revisió de la literatura relacionada amb l'espècie més porpera nosaltres, l'*H. neanderthalensis*, del qual s'ha dit que no podria parlar com nosaltres degut a la seva morfologia. He intentat recollir el màxim d'informació relacionada amb la capacitat de vocallitzar i aquesta espècie i l'he anat contrastant. Després de revisar una dotzena de trets, els més característics han estat examinats en relació a la seva possible absència o presència en aquesta espècie tan propera a nosaltres. La meva conclusió és, de moment, res assegura que els Neandertal no poguessin emetre sons de parla com ho fa l'*H. Sapiens*.

La tercera part està centrada en un aspecte que actualment és encara el centre d'artenció: la recursió i la possibilitat que tenen els humans de produir estructures lingüístiques que obeeixen processos recursius d'estructuració. Primer revís la idea que tenen diversos autors sobre l'evolució del llenguatge i sobre la recusió. Després dedic un capítol al terme recursió i a presentar diversos escenaris que cercant aquell que pugui conjuntar-se adequadament amb la informació que tenim avui dia en els estudis sobre evolució. Finalment, després de suggerir que és possible detectar els efectes de la recursió en altres activitats humans que no siguin lingüístiques, faig en col·laboració amb altrs dos autors, una anàlisi empírica de converses de tres nins, els quals aprenen tres primeres llengües diferents – neerlandès, alemany i castellà – i hi aplic una representació pròpia de la física, les xarxes, mostrant que el llenguatge es desevolupa en infants seguint dos processos diferents: el primer és lineal, mentre que el segon és no lineal. El segon procés produeix xarxes d'escala lliure, les quals a més a més mostren la característica particular de ser xarxes de petit món, és a dir, que tenen un nombre elevat de coeficient d'agrupament, mentre que tenen un tendència a escurçar la llargada de la drecera entre un punt i un altre, gràcies a la proliferació de enllaços.

La quarta part està dedicada a la dualitat de patró, un concepte que tornat a guanyar

rellevància en lingüística que dóna compte de la propietat que té el llenguatge de crear unitats significatives partint d'un conjunt limitat de primitius sense significat. Revís a profunditat els treballs sobre això de l'autor que ho formulà, Charles Francis Hockett, i recuper la definició original, mostrant que està relacionada amb una propietat de la senyal emesa, i no pas amb un mecanisme cognitiu, de tal manera que l'estudi del llenguatge es retroba amb la teoria de la informació, una branca de la física. Tot això m'ajuda a comptar amb una noció clara de la dualitat que pot ésser aplicada fora de la lingüística estricta, a altres sistemes que processen i envien informació en senyals creades sota els mateixos principis. Un exemple és el sistema de crits d'alarma de les cercopitec de Campbell, un primat de l'oest africà, el qual té un sistema de comunicació amb senyals diferents. Després de mostrar que aquesta espècie no fa ús d'allò que formalment en deim "morfema", assenyal que sí que es pot concloure que el seu sistema gaudeix de la propietat de la dualitat de patró, entesa en el sentit original de Hockett, explicat a la secció anterior. Finalment faig unes conclusions que resumeixien els aspectes més importants d'aquestes seccions, tot apuntant cap a futures investigacions i línies de recerca.

I

INTRODUCTION

1.1 The study of language evolution

The present dissertation is a collection of previous shorter works, all of them aiming the same target: language as a cognitive faculty. In particular, I am interested in the evolution of such a faculty. This area of study implies some advantages and disadvantages. The advantage is that there is a lot to do. We know relatively few about human brain evolution – though much more than forty years ago – and the study of the evolution of language related to the evolution of the human being has not been addressed by many scholars. However this is a two-edge sword, since this makes sometimes difficult the task of finding new pieces of evidence or to know other author's opinions.

In the last years the number of publications related to language evolution has notably increased. And so the conferences and workshops, being these headed by the biannual conference on Language Evolution or Evolang (e.g., Smith, Smith & Ferrer-i-Cancho, 2008; Smith, de Boer & Schoustra, 2009), which has captured the attention of many scholars, not just from linguistics. In this sense, though still incipient, new lines of research on this field begin to emerge.

In a recent lecture, Chomsky has stated that: "you can't say much about evolution of language, almost nothing. I think that's the reason why there are so many conferences and volumes and libraries and so on, there's essentially nothing to say – so you have a lot of talk about it." (Chomsky, 2011)". Well, I would like to be more optimistic, and I hope the reader will too, after reading this dissertation. However, it is true that the majority tendency is to look at *language not as a natural object* and hence becoming *linguistics a natural science* in Piattelli-Palmarini & Boeckx's (2005) terms, but as an entity that belongs to humanistic studies only and therefore cannot entirely be explained in natural scientific terms. The approach to language is in most cases from purely theoretical linguistics with some incursions and cites of works on anthropology – the classics, mostly. For many years it has been said that linguistics could be a branch of psychology, though the interaction between this two fields still remains scarce. Indeed, the term "interdisciplinarity" appears often here and there, but it is almost absent in practice.

The present thesis aims to be different in this sense. I have bet for interdisciplinary work, meaning that I had to integrate paleoanthropology, genetics and linguistics, trying to build a coherent framework in which different disciplines get on well. My research on the particularities of language has finally led me to know that there are many indicators

that point language as a complex system. Hence, I've also advanced into complexity, and Information Theory. This field in particular has proven to be of enormous interest, specially in those aspects directly related to language. Although language, in the present work, is to some good extent, conceived as an intern thought device, the way it is externalized deserves attention. Happily, I've been able to apply complex studies to these two aspects of language. Thus, I could make progress in the study of the ontogeny of syntax, analyzing natural data by means of small-world networks; and I recovered from the past Hockett's work on duality – not just his classic papers in the late 50's, but the subsequent works in the 60's until the 80's –, showing that his intuition was closer to complexity and information theory than to philological point of view adopted by many linguists.

Of course, there is still much to do, but I think that now I count on a good basis for future research.

1.1.1 The field

Language evolution has been addressed from many perspectives. Darwin himself has a section on this particularity of human cognition. In fact one becomes surprised, when realizes that many things Darwin pointed out in this respect are exactly the same that some authors defend today (Barceló-Coblijn, 2009). On the other hand, it is even more surprising to find some lines of thought in current literature that go back to a pre-darwinian state of the scientific study. In general, the knowledge of evolutionary studies in linguistics is quite superficial, leading once and again to re-start old discussions that have been overcome decades ago in biology or evolutionary epistemology. A classic example is the discussion of nature vs. nurture or that ontogeny recapitulates phylogeny.

The evolution of language has been addressed from psychology, linguistics, computer science, physics... and, besides a couple of references, it is usual not to find bridges between these areas. The authors from a field do not always read the authors from another fields, so that it is relatively easy that an interesting work becomes unnoticed for a long time. This is something I have tried to do here, that is, to build bridges between apparently separated areas of study. Some people call this interdisciplinary work, but given the current status of such perspective in science – almost never practiced nor supported – I'm not completely sure of its advantages. In spite of this, I think that a new and interesting perspective can be obtained from looking to other fields and hence, this is what I have done in order to address difficult issues like, for example, the vocalizations of Neandertals (2.1) or duality of patterning (4.1 and 4.2). The reader will see that many answers are in

non-linguistic works. A consequence of this approach is that the framework cannot be said to be linguistics, nor biology, nor information theory, but something in between. It is called biolinguistics.

1.1.2 The faculty of language

Language can be conceived in many ways. In fact, the authors of books on language evolution do not always put in practice something that is very helpful for the reader: to explain what they understand by language.

In this work, I understand that language is a cognitive capacity of the human being. It is not just a behavior that we have learned but something much more complex that follows a development process during our infancy. Part of this development follow some instructions code in our genes. These genes, however, have to react in a specific environment, the genome, and the whole organism has to react to the natural environment within it lives and develops. Thus, I embrace a perspective that takes into account the genetic information we inherit from our ancestors and the environment in which we as organism grow and develop.

1.1.3 The organ of language

The expression of the "organ of language" is to some good extent linked to the notion of language as cognitive faculty. It is the metaphorical expression for an entity that can be studied independently of other related capacities, like for example perception. Many years ago Chomsky used this metaphor and a great debate arose since it was all but obvious that there is indeed an organ in the brain. It could be that the source of misinterpreting this expression is the tendency of linguists in using metaphors, an aspect probably inherited from our philological past. A dozen of years ago, Anderson & Lightfoot (1999) wrote a paper on this issue making clear – to my view – this question: "the language organ, in this sense, can be interpreted in a functional sense, and not a implying an anatomical location comparable to that of, say, the kidney" (p. 697). This has been in no vain, given that, yet in the XXI century, there are still people who understand it quite literally: "Chomsky states that the ideal entified structure is not somewhere out there, rather it is part of the individual, for it forms an organ in the brain. [...] We have not yet been able to localize one grammatical rule within that big brain of ours." (Gontiers, 2006: 209).

For my purposes here, it makes no sense to continue with the discussion whether or not we can find an organ of language within the tissues of a human being. Hence, I will avoid

such an expression and will use “cognitive capacity”, which I think resumes the principal ideas of Chomky, Anderson and Lightfood on language, and at the same time avoids he possibility that a reader could think that I'm trying to extract physically words or structures from a human pre-frontal cortex, to mention one of the parts of the brain related to language.

1.1.4 Evolution, language and the genus Homo

Although the rest of primates are also of my interest, it is an enormous order within the kingdom of *Animalia*. I have selected the genus *Homo* for obvious reasons: *Homo sapiens* are part of it, and this genus comprises many (extinct) species that are often forgotten in the evolutionary discussion on language. Nevertheless, it is useful, quasi imperative, to make cross-species comparisons, because today there is only one species in the genus *Homo*. Hence, I will take into account the comparative method, and observe other primates’ behavior or physical structure in order to extract useful information for linguistic hypotheses. This kind of research is particularly developed in the section on the Neandertal capability for vocalization (2.1).

Evolutionary studies show how complex can be the evolution of a single organism, prima facie quite simple, like *Caenorhabditis elegans*[1]. This ultimately means that complexity is part of the studies on evolution. Embodying language in an organism like *H. sapiens*, implies the inclusion of such complex perspective too, and highlights the implausibility of making easy generalizations, or discovering “key” factors, and so on. In the present work I have tried to avoid the use of big claims and alleged key factors that apparently solve all problems. I do not believe in such kind of factors. It is true that I have to refuse to offer spectacularity, though I think that the final result gains in coherence with the rest of scientific areas I have dared to touch. In my opinion, the breakthrough in an area of science is possible when the thesis offered does not frontally clash with other well-established areas like biology, physics or psychology. Thus, for an emergent interdisciplinary field like biolinguistics, it is important to pursue coherence with the rest of natural sciences.

The study of the genus *Homo* has been approached from many fields. It is impossible to forget the irruption of genetics in the last years, given that it has closed important debates like the possibility of hybridization of *H. sapiens* and *H. neanderthalensis* – and now

[1] A free-living, transparent nematode (roundworm), about 1 mm in length, which lives in temperate soil environments. Research into the molecular and developmental biology of *C. elegans* was begun in 1974 by Sydney Brenner and it has since been used extensively as a model organism.

Denisovans too – or the single African origin of our species. These important results have serious implications for the study of language evolution, but also for the studies of language as cognitive faculty.

One of the difficulties when I have tried to address the study of language evolution in *H. sapiens* is precisely the fact that the different perspectives we can find in the literature have the tendency to focus on one single factor that explains all and moreover, sometimes is also able to discard other factors. For example, in the discussion whether or not language was something available for H. neanderthalensis, the best works like that of Lieberman & Crelin (1971) were narrowly focused on the possibility for this species of emitting vocalizations like we modern humans do. Given that their model excluded this option, the rest of linguistic aspects were almost automatically discarded. Therefore, it was worth to explore this hypothesis and see, on the one hand, to which extent is the vocal system responsible of the emergence of language in our species; on the other hand, to which extent the information available until now is strong enough in order to shed light on this old discussion about the impossibility of the Neandertal man of vocalizing as we do. At the time I was exploring this particular issue, at the Max Planck Institute for Evolutionary Anthropology, some rumors about the genetic proves of a hybridization case of *H. sapiens* and *H. neanderthalensis* made irruption in the field. What appeared to be an isolated case, turned out to be almost the general case, since, in the extant *H. sapiens*, only Sub-Saharian humans have not inherited part of the Neandertal genome. This fact has closed some old disputes, but it has open new debates, as we will see in the next sections.

Another open front was the tandem of primatology and comparative psychology. Comparative psychology had shown since long ago that many of those features that had ever been considered human only, were shared indeed with other species; in particular cases, like categorical perception, it was the case that all mammals shared the feature. It has been while observing comparative psychologists, what convinced me that it is not possible to make very strong hypothesis when we know so few about the rest of species. My experience at the Max Planck Institute in 2009, the contact to great apes, and to comparative psychologists, have been crucial factors for the accomplishment of the present study. Since many years, for example, at the time of Kanzi, the bonobo, and subsequent studies with the genus Pan, much has been claimed in favor of the presence of some linguistic features, apparently human only, in both chimps and bonobos. Therefore, the inclusion of the observations of the researchers form this fields into the discussion was almost a must. On another particular front, but still within primatological studies, are the results published by Ouattara et al. (2009a, b, c), which have captured immediately my attention. These authors have reported very interesting results of field study, according to

which a species of monkeys, the so-called Campbell's monkeys, made use of morphemes in order to structure their calls. The challenge was impossible to avoid, and indeed it has be perhaps the most interesting works I have read until now and, certainly, these papers have always been present.

Language evolution has also been approached from other areas in psychology that have tried to single out the role that mirror neurons play in human brain and particularly in human language. This was the opposite case to Lieberman and Crelin, since the target was a different channel of expression, namely the hands. Although this does not represent the kernel of the present work, it has also been taken into account, and to some good extent, the particularity of mirror neurons in *H. sapiens* have been put to the test. Hence, in when talking about Neandertals I will state that it is quite difficult to argue against the presence of such neurons in the Neandertal brain.

1.1.5 Two classics: recursion and duality of patterning

This thesis tries to deep in the notion of recursion and how this notion relates to other aspects of language. To understand better language we have first to agree about what the notion of recursion means. As I will explain in the chapter on the evolutionary scenarios for the emergence of recursion, since the famous paper written by Hauser, Chomsky & Fitch (2002) specially, there has appeared a plethora of papers talking on recursion. However, when one takes a close look to these works, however interesting on their own, one realizes that the most of the times the discussion is futile, because there are very different notions of recursion in each side of the discussion. Moreover, although it can be well defined in linguistic terms, it is not always easy to see how recursion has to be understood outside theoretical linguistics. It is been show that when it has been the time for applying to empirical work, like in a behavioral experiment, it is really difficult to conceive a task, or even a single stimulus that has included recursion in way that can be proved unambiguously.

In our times recursion is still a battlefront. We should somehow clarify not only the notion in linguistics, but also be able to apply it to biology or psychology. How recursion can be related to our cognitive system, or whether or not recursion can be observed in non-linguistic tasks, are recurrent aspects along this thesis.

It has seemed to me unavoidable the inclusion of duality of patterning in the discussion. This is not an easy notion to grasp in linguistics. I'll show that one of the historical problems with duality, is that scholars have usually paid attention just to a couple of Hockett's works (especially Hockett 1958, and 1960; sometimes also 1978). This

has been done in a way, that very different odd readings of the same text have been uncritically spread across the board. Several important aspects related to Hockett's duality can be found in different pieces of his bibliography. In spite of the apparent general idea, Hockett refined the notion through time, explaining mre and more aspects of it in different works. Furthermore, Rosselló (2006) has made evident the current scholars' tendency of citing duality without looking at the original source, so that the distortion of the notion has reached its completeness.

1.1.6 The ontogeny of language and complex systems

As I have already observed, I do not share the old argument that states that ontogeny recapitulates phylogeny. However, this does not imply to reject the information studies on language acquisition can provide. I think it is part of the study of language as cognitive capacity, and hence, I also think that it can shed light on many aspects of linguistics and evolutionary studies. Given that I have dealt with two classic notions of language, namely, recursion and duality of patterning, it seems justified the inclusion of an empirical work that puts to the test some aspects of the theory.

The strongly formal theoretical works we find today in Information Theory and Complex Systems studies, in addition to particular aspects of language suggesting complex behavior, have convinced me of paying attention to some formal properties and complex phenomena we find in nature. Moreover, a series of studies have pointed out that language could be a kind of self organized system, challenging to some extend the assumptions related to an innate character of language, the genetic predisposition humans for language acquisition seem to have, and hence they also implicitly challenge the idea that language is a cognitive capacity evolved in human beings. These approaches observe language from an external point of view, and have focused their attention to the observable behavior of words in several corpora. Therefore it made sense to try to explore in an empirical fashion the alleged complex character of language, from a different perspective regarding these approaches. That is, that language develops in a human brain; it is acquired and developed during infancy, not a cumulus of data printed in a book which, although it surely is a reflection of a linguistic capacity, it loses most information about the mind was behind the text. In fact, these studies are a challenge for Theoretical Syntax, given that a good part of the relevance of syntax is indirectly called into question.

We therefore have conducted an extension of an empirical, innovative experiment carried out some years ago (Corominas-Murtra et al., 2009). In this experiment two English children corpora from the CHILDES data base – which is specialized in language

acquisition studies – were syntactically analyzed. The resultant structures were then sent to a network analyzer, which was able to interpret this information in terms of networks. The result were a series of networks that let see the evolution of syntax in children. The results were very interesting, suggesting a predisposition for the development of syntax, a process that at least underwent two different phases: a first linear development process, followed by a non-linear process of rapid increase of syntactic relationships between words. Our study represents a further analysis of three corpora of three different languages – Dutch, German and Spanish – which aids us to support some preliminary conclusions made by Corominas-Murtra et al. (2009). At least, this new analysis of natural data is the proof that the behavior of the pattern of syntactic development observed in English is not a peculiarity of this language, rather three new languages seem to follow the same developmental pattern of syntactic growth.

It will be the future research, based on the integration of information from neuropsychology and genetics, which will show to which extend, what we have found – a developmental pattern of syntax with interesting particularities – , informs us about the evolution of language as cognitive capacity.

1.2 *Homo sapiens:* the final stage by default

One aspect that becomes repetitive in the literature is that only one species has reached language: *Homo sapiens*. It is indeed surprising to find such an affirmation across the board, given the fact that (1) we know very few about the evolution and preliminary stages of language as cognitive faculty and very few about other extinct species, and (2) theoretically it seems that, if we follow Chomsky, we have nothing to say. Yet, to the latter statement it should be included that we still can either affirm that our species is the only one that has reached language.

We can find that part of the blame of this uncritically spread idea has its origins in the efforts in the last two decades of presenting Linguistics as a serious natural science. Sometimes these efforts have been accompanied of overdimesioned statements regarding language. The second factor involved is the author's responsibility. Language has since long be considered just a kind of cultural accident. Apparently, just the logical response to the wish of hominids for communicating. Everybody wants to communicate, hominids included; hence, the logical idea could be to think that they evolved a linguistic capability for communicating. Thus, often the functionalist resource, "what the common sense tells us", is the only way to see language. Nonetheless, as Hinzen (2011) has pointed out, "A tight coupling between input and ouput has been assumed; structures are specified for a particular function. Evolution, though, does not design solutions for specific tasks." (Hinzen, 2011: 423).

In addition, if we think that the link between language and thought seems to be almost unavoidable – regardless the internistic or externalistic view one can have of it –, language becomes bestowed with the power of dominating the world and all beasts. This kind of thinking probably tracks back to the Bible, though let me leave this matter for a future work. The fact is, that the some of the prominent names in the literature of language evolution have pursued this idea of language as the "key factor" of human evolution. Language is presented as something almost incredible, that allows us to go to the Moon and to be the successful species which have won in the Struggle for Existence, to put it in Darwin's terms. We cannot say that this is not a tough strategy for presenting the study of language almost as a matter of life and death. For example, Lieberman (1992) argues that the kind of 'speech' held by Neandertals was the genetic factor that provoked their extinction. Almost twenty years latter, Bickerton says something alike: "It is essential to

understand the stark contrasts between the fact that every other species that has ever inhabited the earth has manage its affairs and fulfilled its communication needs, whatever they were, perfectly will without anything resembling language, and the fact that language gave the one species that developed it effective command and control over all other species." (Bickerton, 2010: 201). Well, what more can be said?

In this study the way to approach language will be radically different from these quotations above. Let me continue quoting Hinzen: "What evolves is adaptability, the ability to use given resources that have a generic character to new tasks, and to scale up given solutions when new adaptive challenges arise" (Hinzen, 2011: 423). My strategy basically consists in approaching language as part of our mind, physically embedded in the human brain, and hence taking into account as many factors as possible. The strategy of looking for the "key factor" that makes humans special, or the key factor that makes language unique in the natural world is sterile to me, since it offers just a particular, minimal piece of the story (this particular view of science is specially evident, justified an put in practice in the chapters 2.1, on Neandertals, and 3.1, on approaches to language evolution). Language is part of humans, a species of the kingdom Animalia. Our inclusion as animals ultimately means that all physical laws that affect the biological world, affect humans too. Therefore, the way other animals or plants are studied is the way humans must be studied, included particular aspects like language. Again, we could loose spectacularity to someone's view, though we gain in coherence with the rest of natural sciences.

It is particularly due to the last developments in genetics that such insistence in presenting language as something almost incredible is now on the ropes. In fact, we should say that almost all theories on language evolution are on the ropes, because they consider language as something that has happened only once, and in one single species, the *Homo sapiens*. As I will explain in the next section, the proved hybridization between humans and Neandertals, and humans and Denisovans, call into question this assumptions on the particularity of language as such, which were taken for granted without evidences.

We can identify two main streams in language evolution theory. The first approaches language as a feature that has evolved slowly, through many stages. At each stage, a new level of complexity has been reached. I call this stream the Gradual Emergence stream (GE). According to GE, syntax has suffered a continuous and slowly process of getting more and more complex until it has reached the current state. Some of the proponents of such hypotheses are Hurford, Bickerton, Tallerman. These authors concede to *Homo erectus,* for example, the use of rudimentary forms of Noun and Verb. The idea behind GE

is not new. In fact, as in the case of the biblical reflection on *H. sapiens* as "the chosen species", GE is, as a last resort, nothing more than the reflection of an old idea rooted in the occidental scientific culture: ontogeny recapitulates phylogeny. Thus, the ontogeny of a language within a community, must recapitulate its phylogenetic history. The idea is that if a pidging that becomes creolle, is a "simpler" language in comparison to other languages, then it must be a reflection of the past. Why? Precisely because it is the extended version of that idea in evolutionary studies. An old idea, by the way, which has been called into question for good reasons (Gomila, 2010). Alas, the lack of bridges between scientific fields mentioned above, is to some good extent the responsible of these echoes of old failed theories, many years later, in humanities. I will not extend this issue here, since my intention is just present GE as one of the prominent streams in language evolution. Suffice it to say, that such vision neglects the most important fact: creolles are developed by *H. sapiens*, which by default have a modern sapiens mind. How can then this be compared to the cognitive product of the mind of a species that lived 1.8 milions of years ago (mya)? Or, how the historical development of a particular language, which is the superficial expression of a cognitive capacity, can inform us about the phylogenetic development of language as cognitive capacity?

Anyway, GE in its diverse forms entertain the idea that syntax is something that develops in a gradual fashion, and that it becomes a little bit more complex by adding a new element, a new kind of structure, etc. And only our species has reached the last level of syntax. Finally, syntax is considered to be evolved in order to communicate.

A particularity of AE is that considers that evolution is almost linear. After a new change, then can appear another one. It is almost never entertained the possibility that many changes can happen at the same time, or that a single change can trigger a cascade of new changes. The things happen one after the other. AE reflects this naïve vision of evolution on language, so that, firstly, say, there appeared the nouns, then the verbs, then other elements and finally syntax achieves completeness. This old way to consider the evolution is quite surprising, but it is the most adopted one, even by people that are trained in hard scientific fields like physics or biology. It is, as if the organic evolution can follow complexity but language cannot. The common sense is repudiated as adviser in biological or physical studies given that sometimes the things are not that easy, but it is accepted when language is approached.

The Abrupt Emergence stream (AE) differs radically from GE regarding the kind of evolutionary developmental process syntax has suffered in order to be part of our mind. Hence, AE entertains that syntax is highly complex, probably a kind of complex system. Adding complexity to the recipe allows AE to change the rules of the game. Studies on

complexity have shown that sometimes it is not possible for a system to cross the boundaries of complexity simply adding one more element, or becoming a little bit more complicated, or yielding 3 instead of 4. The simple addition of more and more elements does not allow the system to reach the pretended extremely high level of complexity. This is due to inherent rules that govern the system itself. Put it differently, the rules govern simple systems are for simple systems. Adding a new rule does not permit the system to reach a qualitatively different state. The whole set of rules has to be changed for a new one, that permits high complex outcomes. In other words, it is necessary a change in the typology of the system. Thus, the AE stream considers that at some point, relatively near to the emergence of *H. sapiens* as species, something changed in the brain configuration and developmental process of the mind, that allowed the species to do the great leap forward. An abrupt change of system. With new rules, and hence very different outcomes. Highly complex outcomes in the form of utterances, sentences with elements, which show Agreement relation ships between them (e.g., the agreement between subject and verb: "The men walk" vs. "The man walks"); long distance dependencies between non-adjacent elements (e.g., sentences like: "I saw the man who worked in car tired"); Movement of the elements in the syntactic structure (e.g., questions like: "Wherei are you from__i ?"). Furthermore, AE in its various forms considers that the structure of syntax is hierarchical. Thus, all the elements of a sentence follow a strict hierarchic order. The intricacies of the system are so many and so good tied that the system resembles a complex net. And a net is quite different from a string. It is therefore that AE cannot accept that the development of syntax has been so gradual. Gradual development would never reach the whole change of the system, precisely because it gradual change is a cumulus, and hence the system would still bear the ancient simple rules. The typology of the system has to change, according to AE, and this is only possible through an abrupt change. The factors that favored such abrupt change are not clear, but the notion of spandrel, coined by Gould and Lewontin (1979), and the notion of side-effect, have been recovered to the discussion from time to time. The most recurrent argument in the variety of proposals that can be gathered under the umbrella of AE, entertains the possibility that a small change in the organisms has triggered major changes in the brain organization, yielding a new system of mental organization, called syntax[2]. For AE, syntax has evolve purposeless. Hence, the externalization of thought is seen as a fortuitous side-effect.

As we have seen, both GE and AE coincide in the fact that *Homo* sapiens is the only

[2] This last aspect can be tinged: the rationalist stream, and Chomsky along with it, contends that syntax is a tool for expressing thought. Other philosophers, like Hinzen, consider that "syntax formats human thought rather than expressing it" (Hinzen, 2011: 424).

species that has evolved syntax, as we know it today. However, it is the negative evidence what supports this hypothesis. In the genus *Homo* there is only one species today. But now we know how to recover important genetic information that put us on good track to discover our past as species. As new pieces of data are provided by many fields like paleoanthropology, paleogenetics or population genetics, some debates end up, and new questions arise.

1.3 Hybridization: its relevance for language evolution[3]

In part, the development of both GE and AE has been possible, thanks to important discoveries in genetics in the last decade. In the early 80's, the recovering of DNA from organisms that are dead since thousands of years was still a dream. This began to change in 1985 when Svante Pääbo and colleagues were able to extract DNA from an Egyptian mummy (Pääbo, 1985), followed in a very short span of time by the extinct marsupial wolf (Thomas et al., 1989). The techniques were improved, since researchers saw that DNA contamination was something common and easy to happen (see Pääbo et al., 2004 for a review). These results were promising, because they suggested that, in theory, there should be possible to extract DNA from old hominid bones. And this idea was finally carried out, first with the mitochondrial DNA (mtDNA) and then with the nuclear DNA (Krings et al.,1997; Krings's et al., 2000). We know today that Neandertals had the same FOXP2 that human beings have (Krause et al., 2007), that some of them had a similar blood-group O (Lalueza-Fox et al., 2008), and that they had independently evolved red hair (Lalueza-Fox et al., 2007). Thus, the genetic data increase with each extraction. There is much to do, since the reaction of the genes is still not well understood. By reaction I mean that the so-called expression of a gene, it is know to be partially dependent of the genetic environment where it is. Thus, the same FOXP2 could express in Neandertals differently than in humans. Although a great similarity is expected, given the close relationship between these two species, one cannot assume that both species are completely equal regarding a particular aspect, until the expression of the gene is completely understood in both species.

1.3.1 Change of scenario

2010 is the year when the whole paradigm changed, and the a great debate was finally closed. Green et al. (2010) have published their draft sequence on the Neandertal genome. The authors provide proves supporting the hybridization between these two species. In addition, they corroborate the hypothesis put forward by Cann, Stoneking & Wilson (1983) on the unique African origin of our species. However, Green and colleagues' results refuse part of this classic theory in proving hybridization. I would like to stress that,

[3] A previous version of section 1.2 and 1.3 was presented at the workshop "Advances in Biolinguistics" within the *44th Annual Meeting of Societas Europaea Linguisticae*. 8-11 September 2011.

technically, Green's et al. results show a case of introgression, what means that it was not the case that from two species we get a new only, disappearing the two originals. What seems that happened is a case of introgressive interbreeding, namely, that the two species got in contact for a short period of time (short, in evolutionary terms) and that part of the Neandertals interbred with part of sapiens. In fact, the results show that all modern human populations in the planet, excepting one group, are descendants of that hybrids. The group that it is not, are precisely the descendants of those *H. sapiens* which never left Africa, the Sub-Saharian populations.

What this ultimately means for language evolution theory, is that both GE and AE are in trouble. Because, if both groups of descendants and non-descendants of Neandertals can acquire language, and all languages in the world show the same structure and follow the same structural and developmental patterns, maybe it is because Neandertals also had language as a cognitive capability. This is one of the possibilities, though there are more we could imagine.

But the scenario has become even more complicated. Recently, Krause et al. (2010) published an analysis of DNA of an unknown specimen, the so-called 'Denisovian hominid'. It is for sure a hominid, and lived 40k ago in the middle of Siberia, at the Denisova cave. Interestingly, 100 km far away from that place, the Teshik-Tash cave (Uzbekistan), at more or less the same time, was inhabited by Neandertals — as Krause et al.'s (2007) DNA analysis has confirmed. A first datation suggested that the common ancestor of Denisovians on the one side, and Neandertals and modern humans on the other side, dated from 1 mya. Hence ,it could well be a descendant of an Asiatic *H. erectus*. Nonetheless, two recent works have shown that (1) Denisovians were closer to Neandertals than to Sapiens, and (2) that Denisovians interbred with the Sapiens that reached southeast Asia and Oceania (Reich et al. 2011, Vorobieva et al. 2011). What seems evident is the fact that the diversity and co-existence of hominids in some areas was something usual before the exit of *H. sapiens* from Africa.

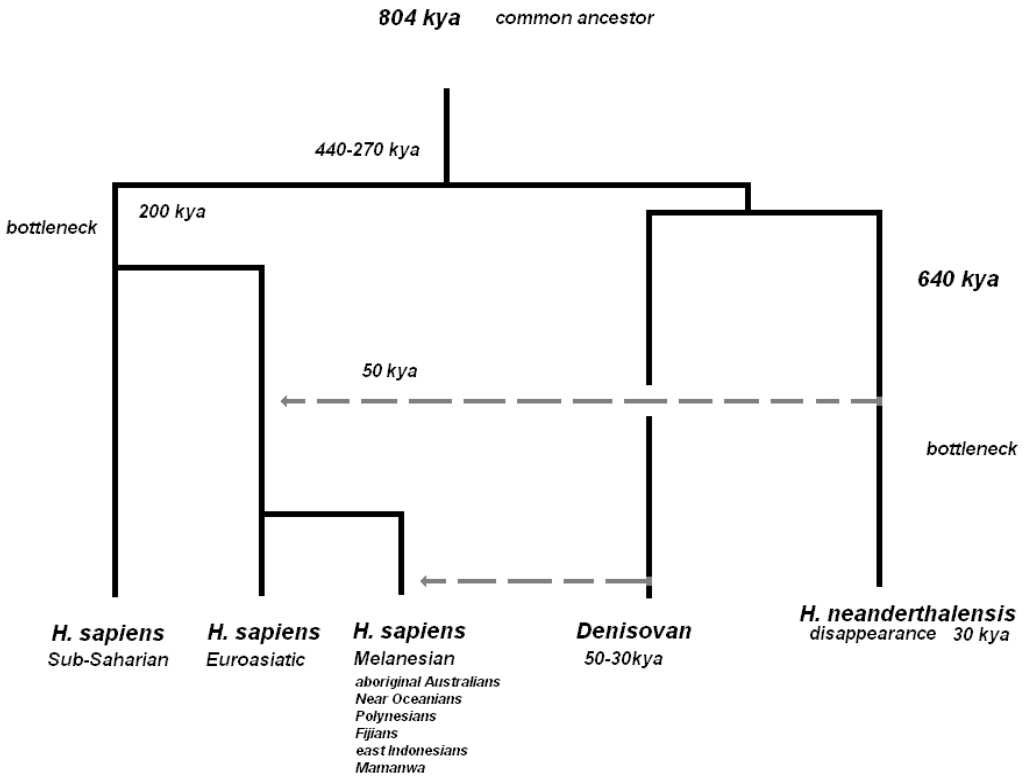

FIGURE 1: schema of the evolution of *H. sapiens*, *H. neanderthalensis* and Denisovans. After a severe population bottleneck in Africa, *H. sapiens* went out of Africa. During the expansion of our species around the continents, our ancestors interbred with, at least, two species: *H. neanderthalensis*, and then with Denisovans. Note that this means that some populations in Asia are the descendants of two episodes of interbreeding.

Green's et al. *Draft squence on the Neandertal genome* (2010) shows that the percentage of Neandertal DNA is more or less the same in Basque people than in the rest of American populations or Aborigins in Australia. This has been interpreted as the result of a single event, large enough to make the genetic incorporation something general in all the groups, but stopped at some point. In other words, when *H. sapiens* went out of Africa, apparently they met Neandertals and interbred. The resultant hybrid group grew and split off. A branch of this group went East and finally got Australia, though previously, they interbred with Denisovans. The remaining group went to West, invading Europe. However, there is no reason to think that they continue interbreeding, since no significant differences have been found when the genomes of Europeans, Americans and Asiatics are compared. Some South-east Asiatic populations (not all of them) have in addition the incorporation of Denisovan DNA.

Seeing figure (1), it is difficult to affirm without clear evidences that that other two species, Neandertals and Denisovans, did not possess language as part of their cognitive endowment. I really think that these new information forces us to consider at least the

possibility that they could have language, while waiting for new pieces of evidence. Clearly, for now categorical statements fall short of being convincing.

1.3.2 Challenges for hypotheses

How deep these new data affect both theoretic streams is something important. Because as I will show, both visions of the evolution of language face a serious problem.

On the one hand, the GE stream favors more than AE the emergence of language in all three species:

1- The fact is that, if language has evolved so gradually, and all three species have had no problems for interbreeding, it could be said that a simple error of calibration allows all three to evolve language. Simply, the last stage of syntax would have been reached before they split off. Hence, the uniqueness of language in *H. sapiens* could no longer be held.

2- In order to overcome the problem, the GE stream, which is also based on the communication argument, should also be able explain, how is it possible that these species, so close genetically one of each other, had not the same pressure for communicate, which, remember is one the main pressures argued for the emergence of language. Altogether leads GE to have to build an independent theory for each species: one telling why communication was more important for the African hominins, and two (perhaps reducible to one) for accounting for the lack of language in Neandertals and Denisovans.

3- The GE stream counts on the population dispersion. In a nutshell, species were separated in therefore only *H. sapiens* could develop the last crucial step towards modern syntax. However, it seems that the affinity between these species was greater than previously thought.

4- A GE hypothesis generally put emphasis on the African group. However, recent findings reveal that the African populations were more diverse than thought, and that there happened more than one Out-of-Africa event.

5- The GE stream bears a tendency often criticized in Anthropology. That is, sometimes the hypothesis are explained in such a way that the place were the species was becomes somehow special. This is since long criticized regarding Europe and the europe-centrism detected in some scholar's work. However, the same can be said regarding the theories on language evolution. Africa becomes the selected land by default, and it seems that every time that a species leaves Africa, it looses the opportunity of developing language due to strange reasons. Accordingly, one can reason out that the whole sub-tribe *Hominina* theoretically descend from the same ancestors, but only our species has kept the importance of communication. Works framed in the GE stream often state that *H. erectus*

already promoted communication, some authors even say that they had already proto-forms of nouns and verbs (Tallerman, 2007). But *H. erectus* went out of Africa and crossed Asia until, at least, Java. This species left behind a group, dubbed *H. ergaster*, from whom we would be descendant. Both groups are so similar that the general view is that they still belong to the same species. Nevertheless, it seems that only *H. ergaster*, according to the reasoning of the GE stream, would have kept pursuing the communication enhancement. This pitfall has not been observed, to my knowledge. And the fact is, that basing the development of modern syntax on communication arguments, forces the proponent to develop new stories for each Out-of-Africa event. For example, some scholars like Bickerton, Corballis, Osvath or Gärdenfors set out the problem of the origin at the clade of *H. habilis*, without paying attention how controversial this species has been, or without mention that it has been posited that the *H. georgicus* found in East Europe could be strongly related or that there is an overlapping between the African *H. erectus* and *H. habilis* (these issues is discussed more in depth in section 3.1). Again, it seems that once a species leaves Africa, by some unknown reason, it abandons the race of the communicative enhancement.

Summing up, in order to hold a theory framed in the GE stream, adaptationists arguments for each species are necessary, increasing so the risk of contradiction due to similar situations for more than one group.

On the other hand, the AE stream, which supposes an abrupt emergence of language as cognitive capacity, generally rejects the argument that language evolved for communication. The positive aspect is that the many problems mentioned above disappear. In addition, AE hypotheses meet the population bottleneck detected in paleo-genetics (Kaessman et al., 2001; Atkinson, Gray & Dummond, 2009). It seems that *H. sapiens* experienced a severe population reduction at some point of their early African history. Some scholars even think that *H. sapiens* almost became extinct[4]. Such extraordinary reduction of the population, as I argue in 3.2, would have favored the spreading of modern language. The AE stream also meets the spandrel theory. The spandrel, an unexpected side-effect of a very particular composition of architectural elements, could be the answer to the sudden emergence modern syntax, and hence it would be conceivable an abrupt change of the rules, as I mentioned above.

[4] The reasons are unknown, though there is a controversial hypothesis on the explosion of the Toba volcano, which would have expelled an enormous quantity of ashes provoking something similar to a nuclear winter. Accordingly, this event plunged the planet into a 6-to-10-year volcanic winter and possibly an additional 1,000-year cooling episode. (Ambrose, 1998). The ash cloud would have covered the sky preventing the plants of making photosynthesis and hence shattering the food chain. The recent explosion of the Eyjafjalla volcano (Island) in 2010, which covered an important part of Europe, have recalled that such catastrophic volcanic explosion fall within the range of possible natural catastrophes.

The proved hybridization, however, affects both streams. Genetic results suggest that these hybridization events happened more than one single time. What this means for language evolution theory is that, for whatever reason, language was not an impediment in order to interbreed with the other species. Regarding this, a number of considerations are in order:

- Language develops during infancy, in a continuous process of input-output-feedback. Put it differently: We perceive an input, we interpret it, we produce an output, we get feedback, we perceive this as input... In other words, the whole capacity for perception is involved in production. Hence, a reasonable option is to consider that the perceptual differences between species – if any at all – where not that great. Much the same can be argued regarding the output channel (see 2.1 for that matters).
- Was hybridization not perceived as harmful for the species? It does not seem the case, otherwise, species have mechanisms to detect when the offspring suffer from severe genetic pathologies, as in the case of endogamy, forbidden in almost human cultures. Perhaps, interbreeding wasn't perceive negatively because it wasn't. Or perhaps because, given the affinity, it was difficult to detect the (linguistic) differences.
- Though perhaps it is a too gene-centric possibility, it could be that language enjoyed of some kind of imbalance favoring its epigenesis. In other words, in case of hybridization with Neandertals or Denisovans, language could be favored by some particular reasons. In Mendelian terms, for example, it could be that the biological elements that take part in language were dominant, instead of recessive. Although this is not my favorite way to approach such a complex issue, I must recognize that, for the moment, the information about the expression of the *H. sapiens* genome is not complete at all, and almost inexistent in the case of he Neadertal genome, therefore, what I call the mendelian option, cannot be discarded.
- It could be that, contrary to the main view, both species had the faculty of language, although whereas it was manifest in sapiens, it remained latent in the Neandertal case. It must be noted that, in such a strange possible case, it cannot be due to a lack of social structure. Neandertals had social structure. If well it is true that the archaeological remains suggest that they had smaller groups than *H. sapiens*, it would be surprising that this difference were totally responsible of the lack of language. Again this line of reasoning led us to

arguments related the genetic dominance. Since complexity seems to be an inherent aspect of language, the suspicions is that language as trait probably is multifactorial, and hence, we will not find the gene of language, but several genes that interact in the epigenesis of the cerebral structures which, given the proper input at the proper age of life, develops language.

– The differences found in the archaeological remains point to a higher level of complexity in the remains left by *H. sapiens*. It must be noted, by the way, that linking archeological remains to a species is a delicate issue that has proven to be deceitful in more than one occasion, given the fact that in rare occasions the objects are found in the vicinity of bones or something that can prove the authorship. Anyway, in general the Aurignacian culture (45-35 kya) is ascribed to *H. sapiens*, whereas the Mousterian culture (300-40 kya) has been associated to H. neanderthalensis. Although controversial, some scholars have singled out that there seems to be a kind of cultural stasis in the Neandertal case, given that in more or less the same period of time, *H. sapiens* has developed continuously industrial innovations (until nowadays), whereas the Neandertal industrial culture seems to be anchored at a particular level of complexity. This has been seen as a proof of some kind of cognitive limitations. Nevertheless, we should be careful, because there exist some groups of modern humans that are still anchored at that time, regarding the material culture. In any case, it seems that Neandertals were somehow different, perhaps more limited or, approaching this issue differently, their cognitive mappings were different. As we will see, it has been argued that maybe Neandertals had a different capacity for combining symbols to signs. Specially objects like the stones found in Blombos cave in South-Africa (Henshilwood et al., 2009), which let show an intricate pattern of squares, have been used to support the idea that Neandertal minds were not able to achieve that.
– Another line of thought pursues the idea that *H. sapiens* is the only extant species that has developed the ability for lexicalizing mental concepts that can be externalized later on (either orally or signed). The results on hybridization cast some shadows on a possible hypothesis based on the uniqueness of *H. sapiens* regarding language. Whereas it seems safe to state that *H. sapiens* is the only extant species exhibiting language, I think that, for the moment, we cannot assure that it is the only one in the history.

Thus, although the analyses on the archaeological remains point to some cognitive differences, the time that both species cohabited (indeed, all three species if Denisovans

are included), forces a reconsideration of the Faculty of Language (FL) as part of the Neandertal/Denisovan cognition. However, to prove that these two species had FL complicates even more their abrupt extinction. Language, and the alleged cognitive potential that language triggers, has been posited as the key factor that led *H. sapiens* to supremacy and the concomitant extinction of the rest of members of the genus *Homo*, being them *H. neanderthalensis*, Denisovans, *H. erectus* or *H. floresiensis*.

The conclusion is that both the gradual emergence and the Abrupt emergence streams have a serious challenge and should be able to adapt to the new scenario. The cases of hybridization that have happened in the history of *H. sapiens* cast serious doubts on the main idea held by these to theoretical streams.

As yet happened when the whole *H. sapiens* genome was sequenced, the work to do now is huge. At that time there was the hope that once we had the information of the genome, many answers could be obtained. And indeed many questions have been answered. However, genetics has realized that the information we have about the epigenesis is not complete, and that a gene can show a different behavior depending on the genetic environment in which it is. In other words, we can no longer expect that a gene that exists in two or three different species have exactly the same expression. This means that, although both *H. sapiens* and *H. neanderthalensis* are very similar genetically speaking, they were different species and the expression of similar genes could be different, yield different phenotypes that could affect the configuration of their respective cognition. The task of obtaining the Neandertal genome has been done. Now we have to understand its expression and we should be able to put this information in the proper context, thanks to the work made in paleoanthropology and other branches of science. I think that biolinguistics, understood as the scientific are that tries to understand the biological aspects behind language, could of the contributing areas.

This is what this dissertation is about.

II

The vocal system

2. The vocal system[5]

The next text has been published and the reference is:

Barceló-Coblijn, L. (2011) A Biolinguistic Approach to the Vocalizations of H. Neanderthalensis and the Genus Homo. Biolinguistics, 5.4: 286-334.

[5] The next section is the result of a work begun some years ago. It has been benefited from comments and observations of the audiences at the *VSSoL Conference on Language, Nature, and Cognition* (16-17 July, 2010, Vigo, Spain) and at the seminar "Traces of Neadertal vocalization", presented at the Centre de Lingüística Teòrica (CLT), Universitat Autònoma de Barcelona (17 July, 2011, Barcelona).

III

RECURSION

AND

COMPLEX SYSTEMS

3. Recursion and complex systems

In this third part I will deal with the notion of recursion. This concept is considered one of the most important characteristics of human language. It is related von Humbolt's observation that language creates from limited media an infinity of new sentences. This concept has become the touchstone of Generative Grammar and of the Biolinguistic Program. The relevance of this feature has even been recognized by scholars that do not adhere the generativistic approach to language. Yet, the interpretations of recursion are many. Too much indeed for a concept coming from mathematics. Hence, we deal with a re-interpretation of a term.

In this part I take pains to show how different interpretations of the concept can lead to different views of the evolution of language. Indeed, as we will see in the next section, there are as many as there are scholars. Thus, next section (3.1) will analyze thirteen different approaches to language, most of the difficult to relate to each other without modifying substantial theoretical elements[6]. The whole discussion goes with the famous Hauser, Chomsky and Fitch (2002) as background, since it is indeed the paper that has ultimately stimulated so much discussion. However, I will not analyze this paper, since I deserve a chapter for it (3.2). I'll conclude chapter (3.1) putting forward the following simple idea: if language is complex, let's approach to it from complexity.

As said, Hauser, Chomsky and Fitch (2002) – henceforth HFC – has stimulated the writing of many papers, and the confection of many experiments. A lot of things that were just assumptions have been put to the test thanks, in great part, to the provocative statements one finds in that paper. Yet, the redaction of the paper is so confusing that a plethora of interpretations of the main thesis has appeared in a brief period of time. It is therefore that I think that the notion of recursion deserves to be approached from the view of evolutionary studies grounded on the accumulated knowledge in both biology and physics. As said, in chapter (3.2) I

[6] Chapter (3.1) has been published and the reference is:
Barceló-Coblijn, L. (2011) *Quod homines tot sententiae*. Critical Book review (27 pages). Biolinguistics 5.3: 227-254.

analyze – a set of – different readings HCF has received, and looking for the best interpretation[7]. Taking into account what we know about human evolution, I try to insert HCF's approach into a coherent framework to work with. The main conclusion is that recursion can be regarded as something that is not *per se* encapsulated in language à la Fodor, but that its scope of action could be cross-modular. Such an approach to that concept is useful for other kinds of studies, more related in inferring recursive behavior from non linguistic activity, like for example, the different industries we have mentioned in part II. Could be said that, for example, a *Mousterian* tool does not show a recursive patterning of modeling? This kind of questions has lead me to think in other activities that can be easily find in our current life, but that could traced to our ancestors. Particularly inspiring has been the work by Camps & Uriagereka (2006), which pays attention to the activity of knotting. This programmatic work has inspired me to look for information about knotting, finding that the oldest traces of this activity have been found in pieces of ceramics form the Paleolithic (Adovasio et al., 1997; Adovasio et al., 2005). I conclude this incursion into the research on tools and evolution of cognition with a contribution Antoni Gomila and me made to an interesting debate on this matter[8].

The final chapter is a first step into the world of complex systems. As mentioned above, I think that language could fall within the set of possible complex systems. Hence, it seems justified to build bridges between Complex systems studies and Biolinguistics. Only a truly interactive cooperation will yield significative results for both fields of science. This cannot be labelled as experiment, but as an empirical work. This has been, then, a work in collaboration with other two more authors, Bernat Corominas-Murtra and Antoni Gomila[9]. We have taken as reference a pioneer work in which two huge corpora of children's sentences – which covered the 2nd - 3rd year of the child's life – where syntactically analyzed and

[7] Section (3.2) has been accepted for publication in 2010 and the temporal reference is:
Barceló-Coblijn, L. (in press) Evolutionary scenarios for the emergence of recursion. *Theoria et Historia Scientiarum: International Journal for Interdisciplinary Studies.*

[8] This contribution is an accepted commentary on Krist Vaesen's (to appear, in *Behavioral and Brain Sciences*) paper "The cognitive bases of human tool use" and has the following temporal reference:
Barceló-Coblijn, L. & Gomila, A. (in press). Evidence of recursion in tool use. *Behavioral and Brain Sciences.*

[9] This section has been accepted for revision and the temporal reference is:
Barceló-Coblijn, L., Corominas-Murtra, B. & Gomila, A. (submitted). The ontogeny of syntactic, small-world, networks of three different first languages: Dutch, German and Spanish.

represented by means of networks. The result is, for each child, a series of networks, each of them graphically representing a (conservative) snapshot of the syntactic capacity of the child. In so doing, it is possible to follow the growth of syntax, being the nodes of the network the uttered words and the links between nodes syntactic relationships. We have replicated this analyses using three new corpora from CHILDES data base, analyzing three different languages. Interestingly, there is a similar behavior in the growth of the networks in all three languages, supporting the results found in English.

3.1 *Quod homines tot sententiae*: there are as many opinions as there are men.

Chapter (3.1) has been published and the reference is:

Barceló-Coblijn, L. (2011) Quod homines tot sententiae. Critical Book review (27 pages). Biolinguistics 5.3: 227-254.

3.2 Evolutionary scenarios for the emergence of recursion[10]

Section (3.2) has been accepted for publication in 2010 and the temporal reference is:

Barceló-Coblijn, L. (in press) Evolutionary scenarios for the emergence of recursion. *Theoria et Historia Scientiarum: International Journal for Interdisciplinary Studies*.

[10] Part of this work was presented at *Ways to Protolanguage Conference*, Toruń, Poland , 21-23 September 2009.

3.3 Evidence of recursion in tool use.

A commentary on Krist Vaesen's "The cognitive bases of human tool use"

This contribution is an accepted commentary on Krist Vaesen's (to appear, in *Behavioral and Brain Sciences*) paper "The cognitive bases of human tool use" and has the following temporal reference:

Barceló-Coblijn, L. & Gomila, A. (in press). Evidence of recursion in tool use. *Behavioral and Brain Sciences*.

3.4. Recursion and Ontogeny

Next I present work which considers a final aspect of language: its ontogeny in *H*. sapiens. It is an empirical analysis of natural data from children. This work was made in collaboration with two other scientists, Bernat Corominas-Murtra (physicist and linguist) and Antoni Gomila (philosopher), hence, putting into practice the aimed interdisciplinary perspective. In the previous sections I have mentioned complexity and complex systems as an aspect I think is deeply related to language. In the next section we have applied the tools and notions from physics to the analysis of three corpora from CHILDES data base. Two tools are used: the *DGAanotator,* a program developed for syntactic analysis. This program has been combined with *Cytoscape*, a program for the analysis of networks used in biology and physics. We will see how language exhibits interesting patterns of growth, and some traits that are typical in complex systems, thus strengthening the idea of language as one more of the complex systems one can find in nature.

3.4.1. The ontogeny of syntactic, small-world, networks of three different languages: Dutch, German and Spanish

This section has been accepted for revision and the temporal reference is:

Barceló-Coblijn, L., Corominas-Murtra, B. & Gomila, A. (submitted). The ontogeny of syntactic, small-world, networks of three different first languages: Dutch, German and Spanish.

IV

DUALITY OF PATTERNING AND COMPLEX SYSTEMS

4. Duality of patterning and complex systems

In the III part I have shown that recursion deserves to be taken seriously in the study of language as cognitive capacity. When Hauser, Chomsky and Fitch put forward their program, they never mentioned how words get the structure they get. Some voices rose up pointing out an apparently great mistake. Even is one accepted the basic lines of that program, practically focused in disentangling the biological nature of linguistic recursion, there was no option for the spread assumption that from a discrete set of sounds, our mind creates larger units – morphemes or words – and from this point, we can produce utterances in the form of well structured recursive sentences. It seemed, then, that the previous stage had been neglected. This famous assumption is in almost all handbooks of philology, sometimes under the European label of *double articulation* and sometimes under the American label of *duality of patterning*.

Some years after the HCF – and posterior saga of related papers – the notion of *duality of patterning* has been recovered from the philological past and it has got center stage. There is a major discussion about how one must interpret this notion, and a parallel debate about whether or not it is exclusively human. It is of great interest for the theory on language evolution, because depending on the interpretation FLN must be extended in order to capture also duality of patterning. This can happen if the notion is well understood and it has been proven to be absent in the rest of species. It must be noted that this line of research implies that duality is a kind of cognitive (sub-)mechanism at the service of language. Is it so, however?

In the chapter (4.1) I take pains to describe Hockett's original proposal in his very terms[11]. This notion has received so many interpretations, that it is worth to deep in Hockett's decades-long works. Once we understand better the author, the better will be our understanding of the notion of duality. The results of this investigation highlight that, at least for Hockett, duality was not all a cognitive mechanism in charge of pairing sound with meaning, but a mathematical property of the signals that come from some

[11] This chapter has been submitted.
This work has enormously been benefited the audience's comments, who attended the seminar I gave ("The biolinguistic sense of duality of patterning",) organized by the *Grup de Biolingüística*, (2011, 27th July) at the University of Barcelona. I would like to thank them all the accurate comments, questions and criticisms they made, which have enhanced this final version.

communication systems. This particular formal aspect of duality is of great help because it becomes a notion which, on the one hand, is not stipulative in the sense that it has not been put forward in order to describe something that is *human per se*, but that can be used in cross-disciplinary works, for example, in comparison with other animals' communication systems. I think that a field like biolinguistics must create notions and tools that can be applied by, for example, biologists and physicists. Otherwise, the interdisciplinary enterprise becomes futile and hopeless.

With the clarified notion in the hand, in chapter (4.2) I apply it to a particular communication system which has been claimed to have human-like morphemes: The Campbell's monkeys alarm call system[12]. It is to my knowledge the most complex alarm call system found in non-human primates, counting on eight differentiated calls (Ouattara et al., 2009 a, b, c). In addition, the authors have also described a statistically significative set of strings of ordered calls, pointing to a particular rudimentary syntax (in the original sense of the greek word *syntax*). This issue has two important questions to be solved:

1- Is the notion of morpheme (untouched since Baudouin de Courtenay's definition in 1881) proper for current (bio-)linguistic research?

2- Does this alarm call system exhibit duality, as a property of the signal?

These two questions will be answered highlighting the usefulness for biolinguistics of importing some well-grounded and precise notions from Information Theory.

[12] This work has been benefited from interesting questions of the audience at the *Graduate workshop on biolinguistics* within the *19th Conference of Student Organization of Linguistics in Europe* at the University of Groningen (2011, January 5-8).
This work has been accepted as paper and will appear, co-authored with Antoni Gomila, in the *World Scientific*'s next volume of the proceedings of the *Evolution of Language Conference* (EVOLANG9) in 2012, at the papers section.

4.1 Duality of patterning: a property of the signal, not a cognitive mechanism

It is a familiar proposition that the task of science is

to make use of the world's redundancy to describe that world simply.

Herbert Simon, 1962

The only tenet that might survive the holocaust is the duality hypothesis.

Charles Francis Hockett, 1961

Introduction

Since Hockett's classical contribution, duality of patterning has been considered a distinctive property of human language. However, many different understandings of this concept can be found across the board. They are reviewed in this chapter, and the understanding that fits best a Minimalist approach to language is defended. The critical issue, from this point of view, is how duality of patterning relates to recursion, and whether it should be viewed as a property of language-E or language-I. It is proposed that duality is better understood as an emergent property of the lexicon. Assuming the notion of *edge feature* (Chomsky 2008), we stress the difference between two cognitive abilities: that of *lexicalizing concepts* – at the syntax-semantics interface – and that of *creating a lexicon* – by which lexicalized items get phonological structures. We contend that duality is relevant in the context of the latter only, and should be conceived as an emergent property of a system driven by the requirement of providing different phonological forms to an indefinite number of lexical units. An integrative conception of morpheme is the outcome of this approach, by which we mean that morphemes turn out to be the way to jointly satisfy semantic, syntactical and phonological constraints.

It is common knowledge that one of the structural properties of human language is duality of patterning, according to classical work by Hockett (Hockett, 1958; 1960a), in which he also included several other features: see Table 1. This list can be found in most textbooks that deal with language. The basic intuition of Hockett was that the linguistic verbal signal decomposes at two levels: one of minimal meaningful units, and another one

of discrete, non-meaningful, phonemic units. It is not a simple task to make this intuition cohere with mainstream generative Linguistics, in particular with the Minimalist program, and specially when the evolutionary point of view of Biolinguistics in adopted. Thus, in the influential formulation of a program for the study of language evolution (Hauser, Chomsky & Fitch, 2002) duality of patterning was not even mentioned. On the other hand, work on animal alarm call systems (Ouattara et al, 2009 a, b) has claimed that duality of patterning is also present in other species' communication systems. Therefore, there is some pressure to update this concept, within the framework of current Linguistics and Biolinguistics.

Some efforts have been made in this regard, most notably by Rosselló (2006), who claimed that the HCF (2001) should have included duality of patterning as part of the FLN. Her work has stimulated new reflection on this property of human language, and how it can be accounted for within the Minimalist program. In this work, we will review the different ways to understand duality of patterning that have been proposed, starting from Hockett's own one, and will defend the understanding that best coheres with the Minimalist program to our lights.

Feature	***Species***	***Year***	***Description***
Prevarication	*H. sapiens*	1966	Messages can be false, deceptive, or even meaningless
Reflexiveness	*H. sapiens*	1966	One can communicate about communication
Learnability	*H. sapiens*	1966	Speakers of a language can learn another language
Displacement	*H. sapiens*	1958	Messages may refer to remote things in time and space (or both) from the site of the communication
Duality of patterning	*H. sapiens*	1958	From meaningless phonemes language creates meaningful morphemes.
Productivity/ Openness[13]	*H. sapiens*	1958	Speakers can create and understand completely novel messages.
Discreteness	Hominoids	1960a	Messages in the system are made up of an inventory of repeatable parts; linguistic sounds are perceived categorically.
Traditional transmission	Hominoids	1958	Linguistic conventions are learned by interacting with experienced users.

[13] Hockett (1978: 279) specifically states that both are synonyms. Moreover, this feature can be seen as gradual: "The other major issue has to do with openness (or productivity: Hockett 1959, pp. 33-34; 1960a, pp. 418-20). The references just given offered a nice, neat, all-or-none definition of this property, but it has long since been clear (P. C. Reynolds 1968; Hockett and Altmann 1968) that various degrees and kinds have to be distinguished."
Here it is considered analogous to Chomsky's *recursion* "broadly speaking", since both differ in substantial aspects: *productivity* does not include embeddedness nor the application of a formal abstract rule: "simply the capability of transmitting (and of receiving and correctly interpreting) novel messages. Bee dancing achieves this in one way, human language in others. Further differentiations rest on the devices involved. I think the basic type of openness in human language behavior is that of the topic-and-comment pattern" Hockett (1978: 279)

Specialization	Primates	1960a	Apparent specialization of some organs for language.
Semanticity	Primates	1958	Associative ties between signal elements and features in the world
Arbitrariness	Primates	1958	The form of the signal and its meaning have no logical connection.
Broadcast transmission and directional reception	(Land) mammals	1960a	An auditory|audible human language signal is sent out in all directions, but is perceived in a limited direction.
Interchangeability	(Land) mammals	1960a	Individuals who use a language can both send and receive any permissible message within that communication system
Rapid fading	(Land) mammals	1960a	Message does not linger in time or space after production
Total feedback	(Land) mammals	1960a	Users of a language perceive what they are transmitting and can make corrections if they make errors
Vocal-auditory channel [tactil visual, chemical olfactory]	(Land) mammals	1958	Channel or mode of communication

TABLE 1: Hockett's Linguistic Design Features

In the first section, we will agree with Rosselló (2006) that duality has too often been misunderstood, and will provide a diagnosis for that: an overlooked ambiguity in Hockett's own formulation of this notion. Accordingly, we propose in the second section that duality has to be understood as an emergent property of the external linguistic signal, a property of language-E. We reach this conclusion on the grounds of complexity and information theory arguments, which highlight important aspects of communicative signals that are shown to be relevant to the discussion on duality. In other words, our notion of duality is different from Hockett's, in that it avoids the ambiguity in his notion, but it is also different from proposals to see duality as part of the faculty of language, or language-I. Although we think that the general characteristics captured by duality help illuminate linguistic communication, we find that the classical conception of duality – which makes it responsible of pairing sound with meaning –, once deprived of its implicit ambiguity, is to be viewed as an emergent property of language rather than as a component mechanism within our faculty of language. In the third section we compare two ways to integrate duality within a generative approach, and argue for a model that separates the ability of lexicalization, from the ability of creating a public lexicon. We contend that duality is only relevant to the latter. In particular, it is how an unbounded number of different signals can be possible with a limited set of signalling units. In the fourth section, we compare our proposal to that of Aronoff et al. (2008), which also views duality as an emergent feature of a communicative system. We point out the difference between their proposal and ours: whereas these authors consider duality to be an optional property of human linguistic signals, for us duality emerges as a side-effect of the interface

between FLN and FLB. Hence, no human language escapes from these effects, either oral or signed. In this regard, our proposal coincides with Hockett in the sense that we understand that duality can emerge in other communication systems. Since we, along with Hockett (1958, and subsequent works) and Fortuny (2010), conceive duality as a property of the process of coding information into signals, it is possible for our proposal to consider the presence of duality out of human language. Thus, we finally make some reflections on musical signals, showing that duality can only be part of these signals if the emergent property proposal is accepted. Hence, duality so understood could be a property of the outcome of a general cognitive combinatorial device that could intervene in music as well.

1. Hockett's definition of duality and its ambiguity

It is a widely spread idea in linguistics that both Charles Hockett and André Martinet independently formulated the same idea, about the same time, regarding the distinctive character of morphemes, as the basic meaningful units, made up of meaningless phonological units. The former terms this property *duality of patterning* (Hockett, 1958, 1960a), a notion developed and clarified through the years (Hockett, 1960a, 1960b, 1961, 1966, 1973, 1978; Hocket & Ascher, 1964; Hockett & Altmann 1968); and the latter proposed the notion of *double articulation* (Martinet, 1960, 2003). Both proposals focus on the same linguistic aspect: in the building process of words, there are two differentiated levels or stages. At the first level, an undetermined but discrete number of phonemes merge into a minimally meaningful set called *plereme*[14]. In the present work we will focus on duality of patterning and the notions of plereme and morpheme.

Hockett stated explicitly that duality was a feature of some communication systems. Hence, he chose "plereme" as an abstract term that allowed more general applications, not just to language: "But here the terms "phonological" and "grammatical" make too direct a reference to human language; it will be better to introduce two new terms of general applicability: *cenematic* and *plerematic*. The cenematic structure of language is phonology; the plerematic structure of language is grammar. Phonemes are linguistic *cenemes*; morphemes are linguistic *pleremes*." (Hockett, 1958: 575). The terms "plereme" and "ceneme" were introduced by Hjelmslev, creator of *glossematics* (1957), though today

[14] This unit was called moneme by Martinet, (1957), and plereme (Hockett, 1958, 1960a). The concept of morpheme was firstly defined by the Polish linguist Jan Niecisław Ignacy Baudouin de Courtenay, in 1881: "That part of a word which is endowed with psychological autonomy and is for the very same reasons not further divisible" (in Booij, Lehmann, & Mugdan 2000:345). Note the role of the psychological character of the term morpheme, as a cognitive entity produced by the human mind.

both terms have two interpretations (see Crystal 2008: 71 and 371): The first relates cenemes and pleremes to glossematics and hence to phonology and semantics respectively, whereas the second interpretation has to do with the study of writing systems. Hockett's use of plereme and ceneme fuses somehow the two interpretations:

> "A good many of Man's recent communicative systems show duality: for example, telegraphy with Morse code where the cenemes are dots and dashes and silences of several durations, while the pleremes are combinations of cenemes to which meanings have been assigned (e.g., two dots means the letter "I"), or the Ogham script used by the speakers of Old Irish. [...] It is posible, however, that duality does appear in some other sub-human communicative systems."
>
> (Hockett, 1958: 575)

Hockett considered the term "word" popular. Instead, he used "morpheme" as the technical term. Although, as seen, he stated that morphemes are the linguistic homologues of pleremes, this was valid generally speaking. In Hockett (1961) we find an explanation of why morphs, but not morphemes, are the units made of phonemes. Morphemes, for Hockett, were something broader which can include several morphs. However, according to him a morpheme could either have meaning or not (Hockett, 1947: 333; 1961). Thus, some morphemes are pleremes, though not all of them. It is important to keep in mind that the resultant unit of duality is one plereme only. Curiously, this has not been the standard interpretation we find across the board, probably due to a necessity of making pleremes equivalent to "words" and the fact that not all words are mono-morphemic.

According to the standard interpretation of duality, at the second stage two or more morphemes can combine into larger sets called *words*. We will see how problematic such interpretation is: it does not satisfies current cross-linguistic reality, in the sense that it is all but clear that polysynthetic languages, for instance, make use of *words* in the European sense (Baker, 2002). Julien (2002, 2007), after analyzing 530 languages from 280 families, concludes that the notion of "word" is grammatically irrelevant and that the very linguistic unit, universal in all languages, is the morpheme.

The morpheme, then, is the key: only a morpheme can be a plereme. This is so because, on the one hand, morphemes are endowed with meaning, and on the other hand, duality does not make compounds of pleremes/morphemes. The combination of pleremes into larger units is made by another linguistic feature which must be differentiated from duality: *productivity*.

> "Productivity implies that some messages in the system – old ones as well the new one – are

plerematically complex: that they consist of an arrangement of two or more pleremes."

(Hockett, 1958: 576)

"Productivity must be distinguished from duality. [On an example] In the modified Paul Revere system described earlier, the semantic conventions assign entirely discrete meanings to each whole message, so that each message is a single plereme, and there is no plerematic complexity. The system thus has duality, but not productivity. Conversely, bee dancing is productive, in that a worker can report on an entirely new source of nectar, but bee dancing has no duality."

(Hockett, 1958: 576-577; our brackets)

The final tricky point is that one has to distinguish between plereme as an abstract unit necessarily endowed with the property of *semanticity* on the one hand, and the linguistic morpheme on the other hand. We stress this distinction because, strictly speaking, *productivity* works on pleremes, not on morphemes, so that there is not always a relation one-to-one between morphemes and pleremes, according to Hockett:

"Among the pleremes of a language are some of its morphemes and larger grammatical elements."

(Hockett, 1961: 45)

This is possible because Hockett lumped together morphemes with and without meaning. In essence, Hockett's duality tries to capture a fact that had already been described earlier but in different terms: Von Humboldt (1836, 1971) observed that language makes "infinite use of finite media" (p.70), and that the "synthesis creates something that is not present *per se* in any of the associated constituents" (p.67).

With *duality* a description (though not an explanation) for the pairing of sound and meaning is provided. Instead, productivity accounts for the possibility concatenation of pleremes into larger lexical units, or even into phrases. The resemblance of *productivity* to *recursion* is evident, although Hockett never talked about productivity in the formal terms recursion has been defined within the generative framework. In this work we will use productivity as a rough equivalent to recursion, always keeping in mind the profound differences between both terms, but focusing on their similarities: both notions describe the possibility for humans of creating new messages through the combinations of lexical units; so that there is no largest sentence, because all sentences can be enlarged in an unbound fashion.

Duality has become standard in some handbooks, but in a way that is far from the original. From now on, we will deal with the notion of duality in Hockett's sense, treating

Martinet's double articulation as a virtual synonym of duality, in spite of some differences[15].

In the next sections we will examine the different readings of duality and propose an alternative which tries to cover the morpheme structuring process. Before proceeding, though, some textul evidence is provided to support our diagnosis:

> "Any utterance in a language consists of an arrangement of the phonemes [...]; at the same time, any utterance in a language consists of an arrangement of the morphemes [...], each morpheme being variously represented by some small arrangement of phonemes. This is what we mean by "duality": a language has a phonological system and also a grammatical system." (Hockett, 1958: 574)

> "The meaningful elements in any language – "words" in everyday parlance, "morphemes" to the linguist – constitute an enormous stock. Yet they are represented by small arrangements of a relatively very small stock of distinguishable sounds which are in themselves wholly meaningless. This "duality of patterning" is illustrated by the English words "tack", "cat" and "act"." (Hockett, 1960a: 95-96)

> "The utterances of a language consist wholly of arrangements of elementary signaling units called *phonemes* (or *phonological components*, to be exact), which in themselves have no meanings but merely serve to keep meaningful utterances apart. Thus, an utterance has both differentiating elements and also a structure in terms of the meaningful elements. This design feature is *duality of patterning*." (Hockett, 1968: 12)

> "A communicative system has duality of patterning [...] if its meaningful signals (pleremes) are built out of some convenient stock of meaningless but differentiating pieces (cenemes) which are subject to constraints on arrangement partly independent of any such constraints on the pleremes. " (Hockett, 1978: 275)

It is clear that Hockett's definition has kept almost the same throughout time. Duality is strictly focused on pairing a message with a signal. In the case of human language the signal is a sound or a sign, and the meaning is the semantic content of lexical units. From cenemes, elements without meaning (linguistic phonemes), larger meaningful elements,

[15] Hockett (1987: 146) confirms that "Duality of patterning is Martinet's double articulation (1957)". As Longa Martínez & López Rivera (2010) have noted, the only difference between these two authors is that Hockett considered in addition the linguistic feature productivity as responsible in the concatenation of lexical units at the sentential level, whereas Martinett did not talk specifically about such a feature.

pleremes, are created (linguistic morphemes). Therefore, morphemes are viewed as the very nuclear linguistic units[16]. We find an example of duality in (1):

(1)		English
/k/,/a/,/t/	> #cat#	"cat"

Although the definition of duality seems quite clear, its interpretation has proved difficult. Hockett himself already complained about that, and misunderstandings of his days are still repeated: "For some reason I do not understand, the nature and significance of duality has been difficult to grasp. Many investigators misinterpret the feature at least slightly [...]; or underestimate its importance [...]; or, at the opposite extreme, give it credit for everything [...]; or find it where it is not, as in our English writing system; or confuse it wit *openness* [...]; or with *hierarchical* organization" (Hockett, 1978: 275-276; our emphasis). Thus, Hockett was rather clear in this respect, since he explicitly rejected that:

(a) duality involves hierarchy (as some contemporary authors have assumed: Wescott, 1967; Hurford, 2002; Studdert-Kennedy, 2005; Fitch, 2006). The inclusion of hierarchy is contrary to Hockett's (1961) vision of language. He entertains that phones, phonemes, and morphemes, do not occur in a linearly parallel and compositional hierarchy..

(b) duality creates words and sentences (as assumed in Nowak, 2000; Pinker, 2003; Anderson, 2004; Aronoff et al., 2008; Fitch, 2011, 2010).

(c) duality creates words instead of morphemes (for example, Pinker and Jackendoff

[16] We consider that, by definition, a morpheme must have meaning. At Hockett's time the linguistic school he followed considered the existence of morphemes without meaning, the so called "empty morphs" (Hockett 1947: 333). This is still present in current literature, like the famous e(n) or s, in derived words in some Germanic languages like German or Dutch:

(I)	Dutch
a. bedrijv=en=terrein	"business area"
bedrijf"business, company" + terrein "field, area"	
b. president=s=verkizingen "presidential election"	
president "president" + "verkiezingen" election	

However, there are data indicating these morphemes, which at the same time are the common morphemes for plural, are meaningful. Although it has traditionally been said that such morphemes not always load plurality (Booij & van Santen, 1998: 158), in recent experimental work carried out by Neijt & Schreuder (2009) it has been shown that "users do attach plurality values". Neijt and Schreuder consider spelling as a "more or less fully fledged subsystem of language". In fact, Neijt & Schreuder propose a "multi-tiered, interconnected system in which elements can have several functions simultaneously".

(2005: 212) provide a mix: "two levels [...], one combining meaningless sounds into morphemes, the other combining meaningful morphemes into words and phrases [...].")

(d) duality is equivalent to recursion or leads to discrete infinity (as in Bronowski 1967; Tallerman 2005).

Interpretation (a) in particular has become very popular. Interpretation (b) in turn reports the ambiguity of the term "word". Probably, the fact that most Anglo-Saxon words in English are mono-morphemic has helped to spread this interpretation across the board[17]. In fact, the translation of the *Course in Modern Linguistics* to Spanish also err this point when the list of Hockett's examples of duality has almost only words with two morphemes – something expected from a Roman language. However, the examples in (2) highlight that pairing one word to one morpheme is not the most common procedure in many languages. Nevertheless, Hockett is again quite clear:

- duality creates pleremes/morphemes, it does not combine them.

- *productivity* (recursion) is in charge of combining morphemes.

(2)

a.				Spanish
	step *k1*.	/t/ , /o/, /ɾ/	>	#tor#	
	step *k1*.	/o/	>	#o$_{\text{THEME}}$#	
	step *k2*.	#tor# + #o#	>	*toro*	"bull"
b.				Dutch
	step *k1*.	/k/,/oo/,/p/	>	#koop#	
	step *k1*.	/ə/, /n/	>	#en$_{\text{INF}}$#	
	step *k2*.	#koop# + #en#	>	*kopen*	"to buy"
c.				Dutch
	[...]$_{kX}$				
	step *k3*.	#ver# + #kopen#	>	*verkopen*	"to sell"

[17] Ninio (2011: 5) reports experimental evidence in this sense, regarding the double nature of most English lexicon: "[...] we classify the verbs for their historical origin, separating the native or Germanic sub-lexicon from the Latinate one. The results reveal that, surprisingly, both in parents and young children 98% of the tokens in the clausal core are generated by monosyllabic verbs, and 96% by verbs of native, Anglo-Saxon origin. Although polysyllabic verbs or verbs of Latinate origin are also used by parents, their combined weight in the token count is very slight."

d. Mohawk (Baker, 1997)

$[\ldots]_{k-1}$

step *k*. *Wa'-t-k-atat-ya't-a-'tsu-st-e'*.

FACT-DUP-1SGS-REFL-body-dirty-CAUS-PUNC

'I made myself dirty.' (lit., 'I self-dirtied.')

In its turn, interpretation (d) identifies duality with *productivity-recursion* (Bronowski 1967, cited in Hockett 1978: 309; Tallerman 2005: 9). Hockett strongly rejected such an interpretation, but this is the way many scholars understand duality.

By pointing to the different ways to understand duality, we also become able to diagnose the reason of such a situation: people conceive of duality in terms of a combinatorial mechanism, which is thought to play at two levels: merging phonemes into morphemes, and merging morphemes into higher meaningful units.

On the contrary, duality is a property of a communication system, in the abstract. Hockett conceived language as a communication system first. A system that was able of codifying information into public units: "In a system with duality of patterning, the problems of emission and detection are to some extent separated from those of encoding and decoding. Emission and detection have to do with cenemes; encoding and decoding have to do with pleremes." (Hockett, 1961: 47).

In conclusion, according to Hockett, duality is a property of some communication systems. We agree with him that a system that exhibits duality must be able to encode bits of information into signals. We identify in human language, along with Hockett, phonemes as the meaningless units, homologues to cenemes. Pleremes are the minimal meaningful units of communication systems with duality, hence their equivalents in human language are meaningful morphemes. These units have a cenemic/phonological exoskeleton that enables their externalization. Thus, with Hockett (1978), we conclude that duality emerges when the system combines meaningless cenemes/phonemes in order to encode information. This means that, originally, duality is a property of a combinatorial process, which makes possible to expand the set of public signals. For human language, we identify this set with the *lexicon*.

Now that we have clarified the notion of duality in Hockett's terms, we will see how an initial intuition Hockett had in the early 50's has turned out to be a promisory line for the research on the characteristics of language: information theory, a branch of physics, has explored the properties of communication systems and has deeply contributed to the

understanding of the properties of communicative signals. We will see (1) how it is possible to enrich our knowledge in linguistics about duality thanks to accurate observations made in this field, and (2) that Hockett's definition fits best with a formal definition of duality, which ultimately accounts for a property of the public signal. This altogether will help us in order to put forward a proposal that tries both to integrate duality into the minimalist/biolinguistic perspective and to offer an explanation for the human ability of lexicalizing concepts, while taking into account duality as a property of the signal.

2. Exploring the exolinguistic perspective: What can complexity tell us about lexicalization?

Hockett makes a clear distinction between the two ways of investigating communication in the broad sense. On the one hand, there is the "endolinguistic perspective", mostly related to historical linguistics. On the other hand, according to Hockett (1978: 246), "[E]xolinguistic procedures involve comparing human language with the communicative systems of other animals, trying to discover what is special about the former and how those special features could have arisen". He was also interested in those apsects one can infer from studies with chimps and bonobos, from neuropsychology and also from information theory. Hockett, when pursuing "exolinguistics", aimed for interesting directions that the time has revealed as fruitful for the biological study of language. Today we call this area of study *biolinguistics*.

In 1949 Shannon and Weaver published *The Mathematical Theory of Communication*. It was carefully read by Hockett. He did understand the contribution of information theory to the studies on communication in his review of Shannon & Weaver's work (Hockett, 1953); less known is his *Approach to the Quantification of Semantic Noise*[18] (Hockett, 1952). However, Hockett finally considered futile the endeavor of the mathematical treatment of language, except for sound change (Hockett 1977: 19).

Following Hockett's initially enthusiastic spirit, we think that today there are reasons to be more optimistic. Duality reflects a particular way of coding information into public signals. Particularly, we will explore how specific patterns and behaviors arise in the composition of what we here call the "public lexicon" (in contrast to the internal thought

[18] Hockett had good skills in mathematics (Gair 2006: 603). In this short paper he attempted to provide a mathematical model that quantifies the semantic distance between codes. This kinds of contribution is not surprising, given the importance he gave to some features of language – for him crucial – like semanticity, discreteness, duality and productivity.

lexical items). An important claim we make is that this perspective clearly points to *properties* of linguistic/communication *signals*, though they do not always imply *per se* the existence of a specific cognitive "mechanism" for each of them: some of them could be structural side-effects. In so doing, we follow Studdert-Kennedy's (1998) intuition that "*duality of patterning is not a unique cognitive property peculiar to language, but reflects rather a general physical and mathematical property of the natural world to which all self-diversifying systems necessarily conform"* (Studdert-Kennedy, 1998: 164).

It is along this line of thought that Fortuny (2010) proposes an algorithm for duality and data compression, until now by and large the best approximation to a formal description of duality. In Fortuny's view, Hockett's (human) duality is a *particular* case of the "general" duality assumed in coding theory. Fortuny explores Hockett's notion regarding the function that codifies one or more bits of information, compressing them into *signals,* which are composed by an arbitrary number of *digits*. The Fortuny's equation[19] seems to account for the length of the codifying algorithm of duality. Fortuny shows the great usefulness of such a coding strategy, pointing to the expected existence of something of the sort within human communicative capabilities.

> "[...] Hockett's conclusion that the distinction between phonemes and morphemes appeared in order to avoid exceeding the practical limit to the number of distinct stimuli that any algorithm can discriminate, especially in noisy conditions, can be viewed as a consequence of Shannon's (1948) Fundamental Theorem for a Discrete Channel with Noise."
>
> (Fortuny, 2010)

In most of his works, Hockett considered *discreteness* a crucial factor for the success of human language (Hockett, 1960a ; 1961: 44; 1964: 139 and 143; 1984: 48-50). Fortuny highlights *discreteness* as the prerequisite for duality and that "the emergence in evolution of language of the duality of patterning must have been favored as soon as language was a discrete system[20]" (Fortuny, 2010: 136). This feature has also been stressed by Abler (1989) when proposed his *Particulate Principle*: according Abler, language is complex system whose success is based on the possibility of combining his particles to yield new

---

19 As Fortuny (2010) points out, "the set of morphemes approximately corresponds to the notion of code".

$$L(C) = \sum_{\omega \in \Omega} p(\omega_i) l(\omega_i)$$

"The length of a coding algorithm C equals the summation of probabilities (p) of a codeword (ω_i) to appear, multiplied by the length (l) of a codeword."

20 For the evolutionary discussion, this is indeed a significant difference, regarding Hockett's view of discreteness, who speculated that was available for other hominins than *H. sapiens* (see Table 1 in this chapter), and even speculated that discreteness would have been part of the cognitive endowment of *H. erectus* (Hockett, 1960a).

messages.

Fortuny observes that duality emerges as a property of the combinatorial system, and that it is a "prerequisite for language to satisfy a basic principle of data compression" (Fotuny, 2010: 132). Thus, duality allows the system to overcome expressive limitations inherent of codes that establish a one-to-one relationship between signals and messages. Hence, according to Fortuny, both the compression of meanings into signals and their transmission favor the emergence of "codewords" (equivalent to plereme). Fortuny singles out that duality allows to minimize transmission error (an important worry for Hocket, specially reflected in Hocket, 1984) because it minimizes the "number of distinct meaningful units". He finally confirms Hockett's intuition that it is "the unboundedness of the syntactic procedure" which "provides language with an infinite number of expressions". Hockett never talked about "unboundedness", although he well observed that communication systems have always a finite set of pleremes. In this sense he differentiated between open and closed systems. Human language, then, is an open system, whereas animal call systems are closed systems:

> "From one point of view, a repertory of 100 calls – or of 1000, or 10 million – is just as closed as is a system of 10 calls. A second point of view is more important. Each of the 100 possible calls now consists of two parts, and each part recurs in other whole calls. One has the basis for the habit of *building* composite signals out of meaningful parts, whether or not those parts occur alone as whole signals. It is this habit that lies at the center of the **openness** of human language. English allows only a finite (though quite large) number of sentences only two words long. But it allows an unlimited number of different sentences because there is no fixed limit on how long a sentence may be."
>
> (Hockett, 1964: 15; my stress)

Thus, it is openness/productivity/recursion that triggers unboundness. It is important to remark that duality is a property of the combinatorial system, which by definition has a limited number of possible combinations. Translated to language, we find clear additional constraints imposed on this number of signals, reducing the real set of meaningful pleremes: Fortuny (2010) provides an example from phonology, which does not allow syllables like /kpt/ due to the lack of the feature [+sonorant].

The conclusion is that a system that exhibits duality can produce more pleremes (meaningful signals) than another that lacks duality. However, if the latter has an enormous memory, it could be that the set of signals paired one-to-one was larger than the system with duality. In any case, such a system has a limit, a channel capacity that could be overloaded if the number of signals exceeds its capacity. Duality minimizes this

probability, since allows new combinations with the available material (cenemes) to which new meanings can be assigned. In this sense, Hockett reasoned that:

> "[During language evolution] Something had to happen, or the system would collapse of its own weight. Doubtless many overloaded systems did collapse, their users [non-human hominins] thereafter becoming extinct." (Hockett, 1964: 17; our brackets)

In general, it can be said that duality, as a property of communication systems, allows an "unbounded" (as synonym of unconstrained) combination of cenemes, but the final number will always be finite. In the case of language this number is enormous, though finite[21].

The reduction of signals with meaning observed by both Hockett and Fortuny produces a new effect well studied in information theory and complex systems theory: *redundancy*. Hockett considers redundancy in language a fact unavoidable and inherent to it:

> "No matter what degree of magnification we use in our examination of human communication, and regardless of the angle of approach, we find redundancy. [...]There is also redundancy in the fact that by no means all combinatorially possible arrangements of the distinctive sounds of a language occur as the shapes of forms — actually, only a relatively small proportion of them do. Not all sequences of phonemes (or speech sounds, or letters) make words; not all sequences of words make utterances. Of those that do, some occur much more frequently than others, which increases the redundancy even more." (Hockett, 1984: 62)

As Herbert Simon (1962) observed, redundancy is a characteristic of complex systems. In information theory it has been shown that redundancy is useful for efficient transmission of information, and a lot of complex systems show redundancy in their structure. Indeed, Hockett pointed out that "redundancy is sometimes redundant, which is to say that there is sometimes more of it than we need". A typical example of linguistic redundancy is given in Roman languages where, unlike English, the plural feature is present in more than one element:

[21] Talking on Chinese characters, Hockett makes the following reflection: "But as the system developed, and a larger and larger number of characters had to be devised, it became impossible to keep on inventing completely different new shapes; instead, new characters came to built by putting together pieces drawn from old ones. But this incipient "duality", as an economy measure, never developed as far as it has in languages (i.e. spoken languages). Thousands of characters in use today are built out of hundreds of recurrent parts; the tens of thousands of morphemes in any language are built out of a mere double handful of phonological components, used with amazing efficiency." (Hockett, 1964: 17, ft. 27).

(3) Catalan

El**s** home**s** vell**s** anar**en** plegat**s** i agafat**s** de le**s** man**s**

The-PLURAL man-PLURAL old-PLURAL go-PAST-3-PLURAL together-PLURAL and taken-PLURAL of the-PLURAL hand-PLURAL

The old men went together hand in hand

Interestingly, redundancy is related to hierarchy. Simon (1962), almost at the same time that Hockett and Martinet published their respective proposals on duality and double articulation, wrote his influent paper on the emergence of complexity, showing that both *hierarchy* and *redundancy* play an important role in a particular class of complex systems, dubbed "nearly decomposable systems". Simon (1962) observed that hierarchy is everywhere in nature, but it stands out in biological systems specially, like molecules but also in communication systems. He did not mention language at all, though according to the characteristics he described, language can perfectly be considered a complex system. Indeed, we think that Simon's explanation also describes some important aspects of the process of *lexicalization* in human language. However, in order to move towards complexity, we have to take into account a feature that Hockett never did, *hierarchy*. The benefit of including hierarchy into the process of lexicalization and, hence into the process of building signals, is that human language is better described and moreover can be included in the class of nearly decomposable complex systems. Perhaps, the most important aspect is that Simon's more or less formal explanation does not aim to describe language, but all "nearly decomposable systems" we find in biology: for example, the evolution of proteins, molecules or atoms[22]. Thus, *prima facie* language could formally be considered a complex system[23]. Additionally, Simon's explanation fits well to whatever process of encryption of information, also called "data compression" described above. Thus, if it can well be said that Hockett and Martinet are the first advertising that language has a dual system for creation of meaningful units, it was Simon who described in a simple way the architecture of hierarchical complex systems which, we argue, is also behind language.

Simon's example of a complex system is next reproduced in Figure (1) in order to see

[22] It is worth mentioning the common characteristic shared by language, molecules and DNA (as particulate systems), that is to say, periodicity: "a periodic system consists of a set of constituents such that, when arranged in some natural order, later constituents repeat properties of earlier constituents" (Abler, 1989: 4; our emphasis).

[23] Curiously, Simon's work has almost never been vindicated within linguistics, virtually unnoticed in linguistics. See "Herbert Simon's Silent Revolution", for a review of the depth and scope of his work in science (Callebaut, 2007).

the simplicity of the procedure, and the connection with other systems, like language. Thus, given the following system, we can call the array |ABCD| *a*.

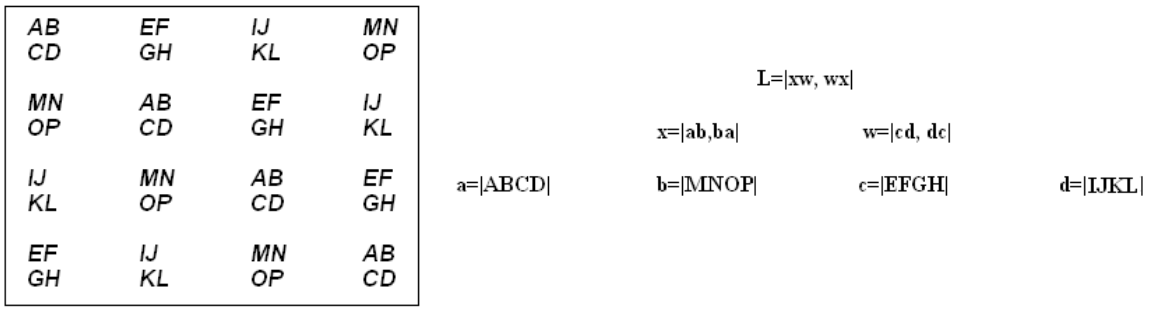

FIGURE 1: Simon's example of a complex system

Every time we find such array, we will replace it by the symbol *a*. We will do the same with the remaining arrays |MNOP| > *b,* |EFGH | > *c* and | IJKL | > *d*. Now, we have to handle with four sets only, namely *a*, *b*, *c*, and *d*, each set containing four elements. As Simon observed "we achieve the abbreviation by making use of the redundancy in the original structure. Since *ABCD* the pattern for example, occurs four times "(p. 478).

Next, Simon goes further and makes new sets of sets: every time we find |*ab*,*ba*|, we will substitute it by *x*, and |*cd*, *dc*| by *w*. As a consequence, the whole code has been reduced to the array |*xw*, *wx*|, called *L*. The economy of systematizing like this is evident: at the beginning there were 64 symbols, instead this re-codification requires only 35. Notice in addition, the pervasive presence of hierarchy, derived from the structure. Simon singled out three types of redundancy forms (p. 478):

1. Hierarchic systems are usually composed of only a few different kinds of subsystems.
2. Hierarchic systems are often nearly decomposable. Hence only aggreative properties of their parts enter into the description of the interactions of those parts.
3. By appropriate "recoding," the redundancy that is present but unobvious in the structure of a complex system can often be made patent. The most common recoding of descriptions of dynamic systems consists in replacing a description of the time path with a description of a differential law that generates that path.

Although Simon never mentioned it, we think that the parallelism with linguistic

codification of information into signals is straightforward: when talking on Fortuny's approach, we have seen that morphemes are units that can encode and compress many bits of information. The Catalan example above shows how the information over plurality has been encoded by the morphemes "-s/-ns" (masculin) and "-es" (feminin). The application of Catalan morpho-phonological rules forces a reduction of the possible combinations of phonemes and this fact produces redundancy. However, redundancy seems to be increased when morpho-syntactical principles join the structure. Hence, the compulsory morpho-syntactical conditions under which morphemes get combined, could also seen as a source of redundancy. Indeed, as Hockett observed, more than we need: Catalan sentence needs 8 times the morpheme of plural, whereas the English sentence has only one.

In fact, if we consider Simon's observations and think in terms of lexicalization and lexical composition, the running process behind the system could go far beyond current human lexical possibilities. In other words, the potential possibilities of the system go far beyond the communicative necessity. In this sense, language would be just a particular type of complex systems. Simon's proposal for description allows the system to go further and further in re-codifying the structure. In fact, this is the basic procedure of programs that compress files: a program requires less space and bits if it has the proper instructions for deconstructing and reconstructing the target object. Nevertheless, although the process of re-codifying and codifying could be quite similar, if not the same, this is not the case of human language. It does not seem that the first function language has is to re-codify again a code (contra Baker, 2003, who states (p.353) that "languages are similar to artificial codes, suggesting that language developed to prevent communication as well as to permit communication"). Instead, it seems that it codifies conceptual units into morphemes, the pieces of the public lexicon. There is the option of thinking that we have a language of thought which is re-codified into the public language, but this an issue we will not discuss here.

We could ask why hierarchy is important for language. Which benefit, if any, a hierarchical structure has in front to a linear structure (the preferred one in Hockett, 1961: 51). There are many types of hierarchy. A linear hierarchy is possible, for example. Another type is the pyramidal one. The reader has probably noted that Simon's example reflects a pyramid and that the combinations are always binary. Although this was just an example, it is a possible one. Chomsky has always claimed this type of structures as the most fruitful ones (Chomsky 2004) In this sense, Boeckx (2011) has stated that such claims are on the right track, and notes that this would be expected if language is

considered from a biological point of view, while recalling Bejan's (2000) work on biological structure, which also supports binary branching as the most successful one in biology. In information theory, pyramidal hierarchic structures of binary combinations have been singled out by Corominas-Murtra et al. (2011b) as the most enriched kind of hierarchies from the point of view of information richness (see Fig. 2). However, a pyramidal hierarchy can vary depending on what kind of combinations take place at each level of the hierarchy, in other words, how many elements combine together under the same dominant node. For example, at the time of the Generative Transformational Grammar it has been explored to which extent the *ternary* combination was suitable for the description of linguistic structures. When trying to describe some morphological processes sometimes the wished *binary* combinations could not be justified and hence the ternary combination was considered as a possible solution. Corominas-Murtra et al. (2011) show that both are possible, but also that there is a difference in the informative richness value. In pyramidal hierarchies, binary combinations only (symmetrical structure) provide a higher level of both informative richness and structural robustness, than the pyramidal hierarchies that allow both binary and non-binary (e.g. ternary) combinations (asymmetrical structure). Instead, the linear hierarchy shows a much lower level of both values of robustness and informative richness (Fig. 2).

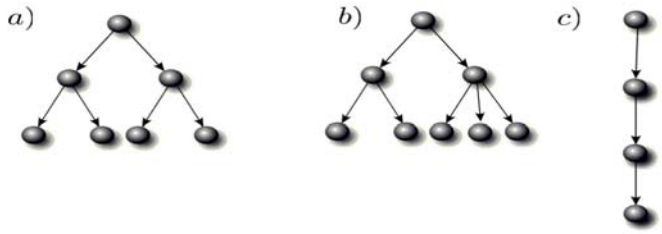

FIGURE 2: Types of hierarchies. Adapted from Corominas-Murtra et al. (2011)

Finally, recall Hockett's words above when talking about redundancy: "Not all sequences of phonemes (or speech sounds, or letters) make words; not all sequences of words make utterances. Of those that do, some occur much more frequently than others, which increases the redundancy even more." Indeed another emergent aspect that affects public signal is the so-called *Law of Abbreviation* (Zipf, 1936). As early as 1936, Zipf showed that the length of a word tends to be inversely proportional to its frequency. Zipf dubbed the *Law of Abbreviation* the statistical fact that the length of a word tends to diminish as its frequency increases. All languages fall under Zipf's law. It is not a parameter that counts for European languages only. In this sense, the human capacity for

externalizing the lexicon obeys the Law of Abbreviation, as one more of the natural laws it obeys. The public lexicon sprouts within the tension created between communicating agents. It could be true that a great deal of such a capacity serves internal thinking, but its interaction with phonology and the externalization process is unavoidable. And all processes of linguistic interaction are mediated by the efforts of speaker and hearer, who both try to code and decode, respectively, and to achieve good communicative results[24]. In other words, it seems that humans cannot escape from Zipf's law (Corominas-Murtra, Fortuny, & Solé 2011).

Our conclusion is that these works point to certain mathematical properties typical of complex systems that could be ascribed to the externalized language. Duality has shown to be better described as a mathematical property that emerges when a communication system needs to make public an indefinite number of pleremes. This seems to be the case of human language and its morphemes. Duality allows combinations of cenemes (phonemes) to yield new pleremes (morphemes), a process that generates *redundancy*, given that not always, and particularly in the case of language, all possible combinations of cenemes are exhausted. Redundancy benefits communicative success. Additionally, redundancy is also increased in conditions of structural hierarchy. Language has traditionally been claimed to be a hierarchical system, in particular a system that follows a hierarchy of binary combinations. Information theory singles out the pyramidal hierarchy of binary combinations as the most robust and informative one. Finally, the redundancy created by duality has another side effect on the signal: the Law of Abbreviation which establishes the length of public signals. This can be gathered in the following schema:

(3)

Combinatorial system	>	duality
Duality and hierarchy	>	finite constrained combinations and redundancy
Redundancy	>	communicative success and signal length

Duality, then, has to be seen as a side-effect that emerges when a communication system recombines primitive elements, yielding new pleremes. As we have seen in the previous section, duality is independent of *productivity/recursion*. For a system to show duality it is not necessary to have recursion. And recursion does not imply duality or vice-versa. Nonetheless, it is obvious that if a system that counts on duality as a property of its

[24] Hence, also capturing to some extent Hockett's "vocal-auditory" view of language.

combinatorial mechanism is put in combination with a recursive system, the communicative potential will increase enormously. Recursion, then, allows the combination of pleremes in order to get new and larger lexical units.

We would like to stress the difference between *property* and *mechanism*. Duality is a mathematical property. A parallelism can be found in sunflower seeds, which are ordered following the Fibonacci sequence. This is a property of the order of the seeds. It is not the case that the mechanism looks for that order for whatever reason. Altogether lead us to think that duality has to be considered a *property* of the signal, rather than a cognitive *mechanism*. It is also expected to find duality in other non-human communication systems, or systems that can be accounted in terms of information theory.

3. Two possible models for duality within Minimalism

In order to talk about duality in the particular human communication system, *language*, it seems that we now need to find a theoretical model of language that can accommodate language as complex system and the notion of duality as an emergent property of the public lexicon. This model should be able to account for mental ability of *lexicalizing* and the ability for creating a public lexicon in an efficient way, that is, compressing the *mentally lexicalized* information into discrete signals yielding minimal meaningful units. Notice that we do not put much emphasis on the physical nature of the signal: since languages can be codified by sounds or by signs, we have to think in terms of *signal*-logy, rather in terms of *phono*-logy (i.e. not focusing just on sounds). The desired model has to take also into account this aspect.

The depiction of duality in terms of information theory points to a system that makes use of "simple" procedures and a minimal set of pieces to yield greater results. It is then, a perspective that deserves to be explored within the *Minimalist program*. This is by no means an easy task, and in addition some of Hockett's ideas have to be tinged and modified – indeed, this was implicit in the previous section. Hockett's vision of duality is concerned with the pairing of sound and meaning, leaving aside whatever structure morphemes could either have or potentially trigger. Additionally, it begins at the phoneme level, at the interpretation our minds make of sound waves. For Hockett, if our mind categorizes them as linguistic sounds, then it probably deals with phonemes, which are by definition meaningless. This is a mechanism well suited for externalism, rather than for internalistic approaches like Chomsky's. Moreover, while Chomsky thinks that language is a well-defined system (specially in the Strong Minimalist Thesis), Hockett thought that

language was ill-defined, "though characterized by various stabilities" (Hockett, 1968: 88). We finally note that Hockett is really concerned with the perception process the hearer carries out. In fact, in 1960 Hockett even wrote a *Grammar for the hearer*. He always talked about the "vocal-auditory" language, channel, or signals, making clear that production and perception was seen as something indivisible. He evolutionary links morphemes first to their acoustic perception, as a pre-requisite for their further semantic interpretation:

> "In at least one case, there was a brilliantly successful "mutation": pre-morphemes began to be listened to and identified not in terms of their acoustic gestalts but in terms of smaller features of sound that occurred in them in varying arrangements. In pace with this shift in the technique of detection, articulatory motions came to be directed not towards the generation of a suitable acoustic gestalt but towards the sufficiently precise production of the relevant smaller features of sound that identified one pre-morpheme as over against others.
>
> With this change, pre-morphemes became true morphemes, the features of sound involved became phonological components, and pre-language had become true language.
>
> [...] With openness, but as yet without duality, the hearer is already required to pay attention to acoustic detail [...]. In pre-language one cannot predict from the beginning of a call how it will continue and end. This clearly paves the way for duality. It is then, in one sense, but a small step to stop regarding acoustic details as *constituting* morpheme and start interpreting them as *identifying* or *representing* morphemes"
>
> (Hockett, 1964: 17)

A Minimalist approach to duality has to boil down the possibilities to those that are crucial for the system, and should be able to distinguish between mechanisms and properties like the third factors pointed out in Chomsky (2005). When reviewing the original sense of duality in the first section we have seen that duality is sometimes confused ore mixed with recursion. The problem is made apparent when one also considers *recursion* as it is described in the Minimalist framework, given that there is a kind of duplicity: both duality and recursion would participate in the concatenation of lexical items. Rosselló (2006) apparently solves this problem separating the functions for each "mechanism":

> "[...] when the unbounded combinatorial capacity came to mediate between sound and meaning, duality would have had to emerge because it was the most perfect solution a

combinatorial system could yield for externalizing conceptual units, in the same way as recursion is the best way to organize complex thought made of conceptual units."

(Rosselló, 2006: 180)

Once it is clarified that duality and recursion are different concepts, we detect two general models of language that could pursue that goal (fig. 3) – of course it can vary from author to author. Let us to explore their particularities and then see which of the two seems to be more suitable for the Minimalist conception of language. First of all, unlike Hockett, in both models all morphemes are considered to be meaningful.

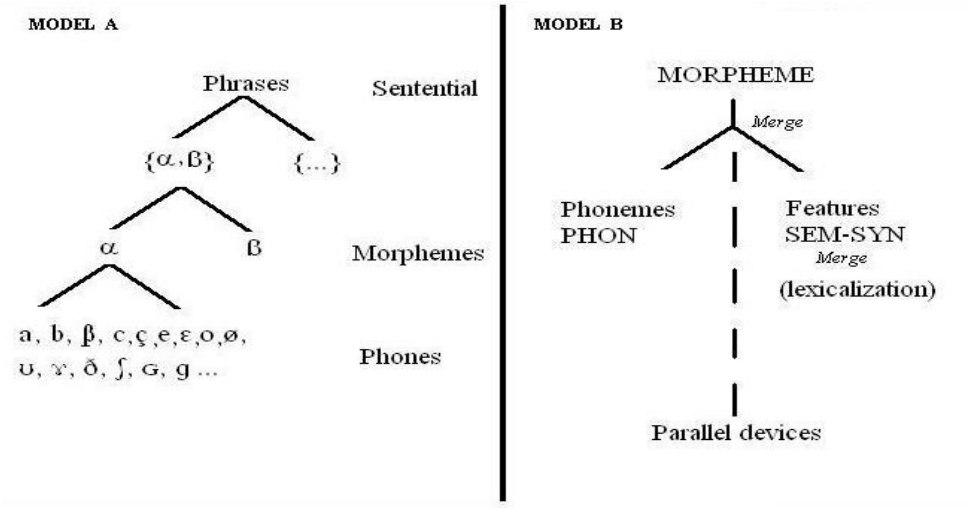

FIGURE 3: Two models for language

It must be noticed too, that both models consider *Merge* as a crucial operation in syntax. A rough description of *Merge* tells us that if the elements α and β *merge*, then they combine into a set {α, β}. If the operation applies iteratively the outcome is a recursive structure {γ, {θ, {α, β}}...}. This operation has proven to be fruitful in the description of language in the last decades:

"As long has been recognized, the most elementary property of language – and an unusual one in the biological world – is that it is a system of discrete infinity consisting of hierarchically organized objects. The simplest such system is based on an operation that takes *n* syntactic objects (SOs) already formed, and constructs from them a new SO. Call the operation *Merge*. Unbounded Merge or some equivalent (or more

> complex variant) is unavoidable in a system of hierarchic discrete infinity, so we can assume that it "comes free", in the present context." (Chomsky, 2008: 137)

The vision of language Hockett had is the opposite to that that considers first the binary combination by means of *merge* of semantic features into lexicalized items. This is quite important in order to understand why duality does fit so bad in most attempts of integration to more generativistic models.

In figure (3) we have the models A and B for the representation of language with the possible participation of duality. Model A considers the existence of a sort of general hierarchy. Thus, at the lowest level there are phonemes, at the middle level morphemes and finally phrases. Rosselló's proposal (2006) implies model A to some extent, at least for the main architectural elements. However, it must be noted in her approach duality has to be applied just to "roots" without grammatical content[25] : "It is important to have in mind the henceforth I will use "word" as a synonym of root. As is well known, a word can be analyzed in subparts, the root being the lexical (not grammatical) atom in it." (Rosselló, 2006: 163). This ultimately means that verbal morphemes are not included. In general, it can be said that these morphemes belong to the closed-class items (functional categories), whereas roots would be part of the "open-class" items[26]. Rosselló assumes that behind duality there is a mechanism that executes its function: to "mediate between sound and meaning". Then recursion deals with the resultant units at the sentential level. It is worth noting that such a proposal fits well a framework like the Borerian one of Acedo-Mantellán (2010) which distinguishes between "the elements carrying *encyclopedic* content, the *roots*, an the syntactic configuration built around functional heads. Argument structure properties exclusively depend on the latter. Furthermore, the syntactic configuration provides *structural semantics* of the linguistic expression. [...] morphology is, by default,

[25] Although Rosselló tries to stick to Hockett's original sense of duality, we think that this application to "roots" was not in Hockett's spirit, not at least in works like Hockett (1947; 1961) in which it is clearly shown that he considered all kind of meaningful morphemes. In posterior works there is also no division of morphemes and thus, our opinion is that he considered all kind of affixes, prefixes and suffixes with or without grammatical content, while meaningful, as part of the outcome of duality. Another aspect to observe is that Chomsky has never taken into account this feature in his proposals. We mean, that the absence of duality in Hauser, Chomsky and Fitch (2002) and in Fitch, Hauser and Chomsky (2005) seems not to be due to oblivion or oversight. It is also true that Fitch (2010: 94) has included duality, also in a wrong interpretation of the type (b) as depicted in the first section.

[26] Instead, Rizzi (2004) considers syntax and morphology two independent formal components of language (p. 446). In his division of open/closed items, the author admits "intermediate" cases (p. 439), like prepositions which "participate in expressing argument structure".

- Open class items (1) have descriptive content, (2) are numerous, (3) are targets of diachronic change and (4) do participate of derivational morphology.
- Closed class items (1) have abstract content, (2) are few, (3) are stable in diachronic change and (4) do not participate in derivational morphology.

syntax, although some specific PF operations can disrupt the basic syntax-morphology isomorphs [...]. (Acedo-Mantellán, 2010:13). A scenario like this, for example, would allow Rosselló to propose the inclusion of duality, along with recursion, as a mechanism into the FLN set proposed by Hauser et al. (2002). Thus, it boils down to the consideration that behind duality there must be a "mechanism". According to Rosselló, both recursion and duality derive from the same human ability for mentally combining elements.

Instead, model B entertains that the phonological form (PHON) is parallel to semantics (SEM). In SEM semantic features are combined binary by means of the operation *Merge* (Boeckx, 2008: 63-120). On the one hand, the notion of *feature* is all but homogeneous (see specially Adger & Svenonius, 2011). However, the kernel of this notion tells us about how information from different modules is reduced to these units, and how they seem to follow some kind of organized distribution, so that in a single lexical item do not converge contradictory information. It is interesting to note that Simon's notion of hierarchy, depicted in the previous section, is somehow richer than the popular use:

> "By hierarchy I mean the partitioning [not the mathematical term] in conjunction with the relations that hold among its parts"
>
> (Simon, 1962: 469, ft. 6; our brackets).

This definition is useful and proper, if we think in terms of "checking features". We would like to put forward that Simon's observations on hierarchy can be complemented by Chomsky's (2005), when said that linguistic hierarchical structure derives from the recursive application of a (set of) rule(s).

Model B, then, entertains cross-modular thought. Each feature becomes a lexical item through the *lexicalization process*, and when a lexical item combines with other lexical items they have to check their compatibility (operation *Agree*[27]). The relations "among its parts" mentioned by Simon can be reinterpreted as *feature checking*, an operation that has been mathematically formalized by Corominas-Murtra (2011), who see it as an interaction based on *compatibility relations*[28]. As Boeckx has pointed out,

---

[27] Once Merge is discarded as an operation specifically emerged "for" language, Agree "appears to be a fundamentally language-specific operation" (Boeckx, 2008: 119). This operation does not appear de novo, but as a result of a evolutionary tinkering process.

[28] "Intuitively, feature checking restricts the operation merge to those cases where some compatibility relation among the sets to be merged is defined. […] Therefore, beyond its intrinsic nesting-like nature, the syntactic object will have a collection of elements that will define the compatibility relations."
For the functions and equations, the reader is referred to Corominas-Murtra (2011).

> "Natural language syntax operates on unites that are characterized as bundles of features. Such features are lexicalized concepts. Syntax creates ever-larger molecules by combining featural atoms through iterated use of Merge. Such molecules, the expressions generated by syntax, provide instructions to PHON and SEM"
>
> (Boeckx, 2008: 63)

What does it trigger in lexical items such a tendency to combine? Both Ott (2009) and Boeckx (2011) have singled out *lexicalization* as the key novelty of our species and argue that one of the promising proposals are Chomsky's (2008) *edge features* which capture the essence of lexical items:

> "For a L[exical] I[tem] to be able to enter in computation, merging with some S[yntactic] O[bject], it must have some property permitting this operation.
> [A lexical item (LI)] has a feature that permits it to be merged. Call this the edge feature (EF) […]. The fact that Merge iterates without limit is a property at least of Lis – and optimally, only of Lis […]."
>
> (Chomsky 2008: 139)

> "It is lexicalization that allows a concept to be enter into the construction of syntactic structure, which in turn acts as an instruction to construct a complex concept/thought […]."
>
> (Ott, 2009: 265)

> "[…] we can think of the process of lexicalization as endowing a concept with a certain inertia, a property that makes the lexical item active (i.e., allows it to engage Merge-relations)."
>
> (Boeckx, 2011: 53)

It is worth to note that according to these authors the lexical item is still an internal thought that has been *lexicalized* (it has basically been reduced to semantic features, which have undergone binary combinations through the application of *Merge*), and it is in a later operation that it merges with the "syntactic object", thanks to the edge feature. This property or feature turns lexical items "sticky" (Boeckx, 2011) in the sense that they are all "mergeable", when the proper lexical conditions allow it. If we accept model B and take into account Simon's and Chomsky's previous observations on hierarchy, the result is that *lexical items* (*morphemes*, though previous to their externalization) can be subject of

further combinations with other lexical items, following a hierarchy as the most important aspect of these combinations.

Interestingly, Model B seems an evolved model – "minimalized" if you will – of Hockett's model presented in (1961), although, we fear, it is a historical accident, since it seems that Hockett's model has passed practically unnoticed until now for generative and minimalist researchers[29]:

(4)

[GRAMMAR SOURCE] – { } → [PHONEMICIZER] – / / → [ARTICULATOR] – { } →

P *P*

(Hockett, 1961: 49, figure 8)

Thus, according to Model B, in principle, there are no differences between the two examples in (5): As in the well-known case of Romance languages, several syntactic features are *fused* (or *compressed*) into one single set of phonemes, whereas in Inuit each morpheme codifies a single semantic feature:

(5) a. Catalan

Compr=à galete

(He, she) buy-PAST-SING-3-IND cookies

"He or she bought cookies"

b. West Greenlandic (Fortscue, 1980:266)

vissaarulluinnalirsimajunnarsigujuq

vvik=ssaq=irut=lluinnar=lir=sima=junnarsi=gi=vuq

turn out-FUT-deprive-of-completely-begin-PERF-probably-and so

'and so he has /had probably begun to be completely deprived of anyone to turn to'

[29] P representes a relation "connecting whole strata" which "runs horizontally". We say that model B "seems" an evolved model, though it is not completely. In another figure, Hockett decomposes de stratus grammar into: [… / sentences / clauses / phrases / words / morphemes] (Hockett, 1961: 48). Hence, it is a perspective more in tune with model A. Note the terminological incoherence of using here the term "word". It is in fact a constant in Hockett's works the variation of terminology, specially of technical neologisms.

The morpheme "-à" in Catalan, previous to its externalization, has undergone a lexicalization process, through which the features it bears (namely, SINGULAR + PAST + 3 PERSON) haven firstly been combined. It is later on and through a different operation, that this resultant bundle of features is *compressed* (à la Fortuny) and encoded into a morpheme, which now has a phonological exoskeleton (the stressed vowel [a]). It is then, when we can talk about a morpheme/word, which is an element of the public lexicon. *Merge,* along with *feature checking,* can account for abstract chains of lexical items, which finally will be externalized through the phonology in forms like the represented in (5).

According to Model B, it is unbound syntax which makes possible an unbound set of arbitrary arrays of phonemes – and hence what it is thought as a mechanism of FLN in Rosselló (2006) here is entertained as a side-effect, a property of the resultant unit. These signals, thus, constitute the lexicon, which makes no distinctions between kinds of morphemes. It is worth noting that according to Model B, the lexicon is not anymore the "repository of idiosyncracies" (Chomsky 1995) but the repository of "grammatical formatives"[30] (Boeckx, 2008: 74).

We would like to put forward the idea that the model B so understood yields and interesting conception of human morphemes: they are at the crossroad of several interfaces, namely, syntax, semantics and phonology. Morphemes, then, as pieces of the public lexicon, are integrative units of information. Thanks to this integrative lexicalization, morphemes contain the semantic information from the semantic features compressed into them through the edge feature; morphemes have a phonological exoskeleton that allows them to be externalized. Additionally, morphemes have a valence, inherited from their previous state as lexical items, which expresses how and with whom can they be combined.

Although we frame this particular conception of morphemes within the Minimalist program, something akin was said many years ago, in relation to the schema presented in (4):

> "Since the diagram shows more than two strata, it may be wondered why I insist on merely the duality of patterning of language, rather than the plurality. The reason is that any patterning in any articulation or in acoustics is one imposed by the "inner" strata, phonology and grammar, with no independent status"

[30] This model follows the basic lines drown by Distributed Morphologists, for whom the lexicon can be divided lexicon into three parts, whose conjunction yields the lexical item:
- Narrow lexicon: grammatical instructions.
- Encyclopedia: information about usage.
- Dictionary: information about pronunciation.

(Hockett, 1961: 49)

> "Under our approach, which defines words primarily as perceptual gestalts, I propose that words ought to be thought of as neither phonological nor grammatical, but as superordinate to that dichotomy and relevant for both." [31]

(Hockett, 1987: 56)

Our conclusion is that Model B explains better the process of lexicalization and at the same time does not add more elements into FLN. The conception of duality as a mechanism of FLN complicates the architecture of mind one the one side, and the evolutionary explanation of the emergence of such mechanism. To argue that recursion and duality are two different elements within FLN that have the same origin, does not solve a problem but creates new one. It moves back in time evolutionary questions and new doubts arise: Where it comes from, how the split happened, or where are they located in the brain/mind. Instead, the conception of duality as a property of the signal puts this notion into the set of third factors, which are indirectly related to language, without adding new questions to the already complicated field. Moreover, duality as property of the signal fits well all these studies from information theory and provides us with a new tool that can be applied to cross-disciplinary studies.

4. Final remarks and further applications of duality

According to the previous conclusion, duality is a property of the signal produced by a combinatorial system. We would like to make some remarks of the substance of the signals in human language. One of the striking differences between the two models is the relationship they maintain with the conception of phonology. According to Hockett duality is a universal of human species and present in all human languages, either oral or signed. This is true indeed, since all human languages encode information into morphemes. In her revision of the concept of duality, Rosselló says "As is well known, Hockett neglected sign languages." (Rosselló 2006: 167, ft 6). This is true just of his best-known papers. The late Hockett (1978), though, recognizes that he read too late Stockoe's (1960) work, which convinced him that sign languages ("signages") are human languages in all respects:

> "Of the various other design features that have been noted as characteristic of language by one or another investigator, most are clearly present in Ameslan (as used by humans). Only one more such feature needs special discussion here. " (p. 275).

[31] In this work in particular, Hockett did not use purposely many technical terms usual in linguistics. Hence the repetitive use of words throughout the book.

> "I think Ameslan has duality of patterning. Stokoe's description of 1960 was already pretty convincing [...]. Supporting evidence comes in more recent studies [...]: in tests of short-term memory, errors made by users of Ameslan are as apt to derive from the physical similarities of signs as from their semantic affinities. " (p. 276)

Although Hockett finally considered sign languages as part of the set of full-fledged human languages, he had held that the origins of duality were back to the hominoid stage, at the beginning of the recognition of sound patterns as linguistic categories, and from this capacity the brain was also able to express the same by mean of signs. This scenario is particularly evident in Hockett (1978), where in addition, he rejects the manual theories of language origins and, wisely, considers that both channels of expression have always been there, complementarily active and available for communicative purposes (Hockett, 1978: 299). Hence, we think that it makes evident the strong relation of dependency between sound, phonology, phoneme and duality. To remain strictly faithful to Hockett's duality posits problems at this level.

A particularity of the Model B is that it considers PHON as the device that deals with sequenced signals that the brain consideres linguistic. In this sense, phonology is no longer exclusively linked to sounds only, but it is "substance-free" (Mailhot & Reiss 2007; Samuels & Boeckx 2009; Samuels 2009)[32]:

> "[...] we adopt a "substance-free" approach, in which the computational system has no access to (and hence makes no use of) the phonetic substance of speech."
>
> (Mailhot & Reiss, 2007: 45)

This approach agrees with the view of phonology as the capacity for recognizing sequenced signals, regardless the channel[33]. From this standpoint, it does not matter if we externalize a structured thought by means of sounds or signs because our brain is ready to interpret and produce signals that can codify it, regardless the modality (like when interpreting

[32] Model A has been implicitly assumed in general by many scholars. Sometimes, perhaps acritically. However, it is not possible to generalize saying that all authors do not consider that behind linguistic sound processing and linguistic signs processing there is the same phonological module or device. In the case mentioned above, Rosselló (2006), given her defense and knowledge of sign languages, we think she could agree, at least at the basics, with a substance-free vision of phonology.

[33] Deadly serious, Hockett & Ascher (1964: 16) said something akin:

> "[…] it was fortuitous, since it was a by-product of changes taking place for a totally different set of selective reasons. […] If early primate history had for some reason promoted precision of control of the sphincter, and of the accumulation and discharge of intestinal gas, speech sounds today might be anal spirants." (Hockett & Ascher, 1964: 16)

arrays of lights which indeed are an expression of the Morse code). It seems that if signals are properly structured and sequenced we can interpret them in terms of communicative signals. A look to the extant (both lesser and great) apes makes evident that these species have followed the majority of mammals in using the vocal-auditory channel for external communication. However, it is also true that our human brain is endowed with a high level of plasticity. This characteristic enables other channels of expression if it is required, like in pathological cases[34].

Finally, we would like to remark the deep differences between the model B we adhere and the vision of duality in sign languages held in some works on the Al-Sayyid Bedouin Sign Language (ABSL). The coincident point is that both proposals argue that duality is "emergent", but due to very different reasons and under a very different conception of the concept. Contrary to our vision is Aronoff and colleagues' (2008) opinion that there is no duality in ABSL – using a quite strange phrase, these authors talk about "duality of phonological patterning" (p. 131). Sign languages, needless to repeat, are fully-fledged languages. Hence, if only by definition, it is surprising that they lack of such a crucial characteristic like duality (either according to Hockett, to Rosselló or to our proposal). This is due to the fact that Aronoff and colleagues consider that signs must be completely equal phonemes. The authors contend that, contrary to Stokoe's (1960) observations on other sign languages, in ABSL "crucially, neither the hand-shapes, the location, nor the movement of these signs has independent meaning" (p. 135) and these elements "do not constitute a discrete set of meaningless building blocks that combine and recombine to create meaningful words in ABSL" (p. 136). Their conclusion is that duality arises only when the number of contrasting signs reaches the threshold. Surprisingly enough, the authors stress that ABSL have words, syntax, lexical compounds, recursion and morphological rules, and in fact they explicitly describe "an open-ended conventionalized lexicon and structural means for expanding it (compounding)" (p. 146). Given such a tool-kit, we do not known what else a language may need in order to exhibit duality. In our opinion, their error lays in focusing on phonology and on the minimal pairs, as evidence of duality – phonemes are the first part, but meaningful morphemes clearly are the most important. Yet, according to the classic term, phonology (along with semantics) is one of the elements involved in duality. Aronoff and collaborators have proved the existence of both phonology and semantics in sign languages. Clearly, the negative evidence of

[34] For example, congenitally blind adults have been proven to process language in the occipital cortex, usually activated in vision tasks in non-blind people (Bedny et al. 2011). Thus, the expression by means of signs in case of deafness, or by rapid eyelid-movements is the prove that, instead of a phonological device dedicated to sound signals, humans possess signal-logy, which makes possible to detect, trace and categorize signals of different nature.

minimal pairs does not rule out the presence of duality in ABSL, even more when signers of ABLS are able to expand their lexicon[35]. Israel & Sandler (2008) continue this line of work and reasoning and compare ABSL with American Sign Language (ASL), and Israeli Sign Language (ISL) and, of course, they find that "[T]he cline of variation is consistently ABSL > ISL > ASL", where ASL is the oldest one (namely, it has had more time "to reach duality"). From these observations the authors conclude that the emergence of duality is synchronically gradual. Such a conclusion and misunderstanding of the concept of duality lead us to think to which extent there is not a confusion with what they see (the "phonetics" of signs) with what signers compute and order according to ultimately psychological principles (the "phonology" of signs).

Indeed Sandler (2010) enumerates a great quantity of elements that form part of the structure of the signal in sign languages, and hence are reflect of the combinatorial processes they undergo. But even so, Sandler insists in the lack of minimal pairs as evidence against a well developed phonology in ABSL (Sandler, 2010: 2731).

> Similarities at the phonological level across physical modalities provide a compelling argument in favor of language as a coherent system. Quite remarkably, sign languages have contrastive phonological features [...], morpheme structure constraints [...], sequential-segmental and autosegmental feature organization [...], allophones [...], hierarchically organized feature classes [...], and syllables [...], as well as other levels of prosodic structure [...] All of these properties may be seen as universal characteristics of language, and sign language research has contributed to establishing them as such. Each, however, is qualitatively different from its spoken language counterpart, demonstrating contra certain modularity hypotheses [...] that a coherent system is not necessarily a modularly encapsulated, domain-specific one [...]
>
> (Sandler, 2010: 2728-2729)

> But in this language [ABSL], we have found no minimal pairs, and we find a good deal of variation in sign production across individuals, significantly more than in more established sign languages [...]. For these and other reasons, we have argued that the ABSL lexicon contains holistic iconic images, and that this fully functional language does not yet have a crystallized phonological system
>
> (Sandler, 2010: 2731)

[35] In our view, the authors err when make equal the "basic property that others have ascribed to protolanguage, duality of patterning" (p. 132) – referring to Jackedoff (1999) – to Jackedoff's "combinatorial phonological system" and then they look for phonological evidence only.

Both Aronoff et al. (2008) and Israel and Sander (2008) have misunderstood the notion of duality, treating it as if it was a gradable notion. It is not. A system has duality or not. Additionally, they have neglected Hockett's specifications on this matter:

> "The duality hypothesis does not rest on the presence of morphomorphemic irregularities in a language (or their analog in some other communicative system). [...] If in such an ideal language, there were exactly the same number of morphemes and of ultimate phonological elements, then, indeed there would be nothing to gain in speaking of duality. But if there are more morphemes than phonemes, then there is duality. [...] Since there are always vastly more morphemes in any language than there are ultimate phonological elements, a language has duality of patterning and would retain that duality even if all morphophonemic irregularities were to disappear. "
>
> (Hockett, 1961: 47-48)

In other words, in natural human languages, the mere presence of a public lexicon, which is much more numerous in units than the set of phonological primitives, does guarantee the emergence of duality as a property of the signal. It is not possible, by definition, to combine a set of elements in order to get meaningful signals, and that these signals lack of duality[36]. But even more surprising, at least in the context of evolutionary studies, is that the authors retake the (apparently) superseded controversy *ontogeny recapitulates phylogeny* – which we reject (see Gomila, 2010): "If its emergence is gradual in a modern human community, it is reasonable to infer that the same was true in evolution." (Israel & Sandler, 2008:)

Sign languages in general are still a challenge for linguists due to the traditional way of conceiving languages and phonology – just orally. On the one hand, signs, however difficult to observe and trace – above all for non native signers – should not preclude the presence of duality, based just on negative phonological evidence and ignoring the rest of linguistic modules involved. The fact that sign languages rely on meaningful signals build from meaningless movements guarantees the presence of duality in the structure of these signals. Nonetheless, Aronoff and colleagues' observations perhaps emphasize a non-

[36] Even the nul set {Ø} of meaningless primitives could be merge with a lexicalized item, if one considers, for example, that it is a morph attached to a root. This is the so-called null morpheme:

(i) Insular (Balearic/Algherian) Catalan	(ii) Continental Catalan
menj-Ø	*menj-o / menj-e / menj-i*
eat [present -1st- sg]	eat [present -1st- sg]
"I eat"	"I eat"

trivial issue: although at the computational level both sign and oral languages seem to be the same, their intrinsic way of externalization could affect them – if only subtlety – being a source of artifacts. It could be that some phonological rules are more suited for one modality than for the other, or that there could apparently be cases of overlapping or even conflict due to theoretical assumptions in phonology which perhaps do not fit data from sign languages.

4.1 First applications: other systems with duality

Now that we have put forward a notion of duality that describes signals of a combinatorial systems like some communicative systems – human languages within them – let us show how we can apply this notion outside language. This is not at all new, since Hockett himself already did it, when looking at the bee dance or bird songs. The utility of having a notion of duality that is not stipulative for human language, allows us to make cross-field comparisons and test whether a particular system shows duality or not, and if it does, what are then the differences and similarities with human language. Let's begin with music.

Music builds whole structures from smaller units built of set of discrete elements. Fitch (2006) reviews the issue and finds similarities and unavoidable discrepancies: "music, like language, is *generative*" and can produce "an unlimited number of *hierarchically structured* signals" (p. 178). However, according to Fitch, music lacks some crucial Hockett's features: *displacement, semanticity*, *arbitrariness*, and *duality of patterning* (p. 177). Why, then, does music lack of duality? Because, as said above, it lacks of semanticity (remember the interdependent relationship between *arbitrariness-semantics-duality*). Although this has been seen as a sign of parasitic coexistence of music, taking advantage of linguistic computational resources, Fitch concedes that "this does not imply that music has no meaning, of course, but simply that the mapping between signal and interpretation is quite different" (Fitch, 2006: 177). May be is because of this kind of curious concessions that Trehub (2003) puzzling can state that:

> "[A]lthough both music and language show duality of patterning (discrete, meaningless elements are combined to produce meaningful structures), the resulting musical pieces are not meaningful in the same way that verbal utterances are. In other words, music lacks "semanticity". "
>
> Trehub (2003: 669)

For Rosselló (2006: 170) instead, this no issue: the lack of semanticity prevents music of having duality. Nevertheless, the structural properties of music partially coincide with those of morphemes, so that if duality is considered as an emergent property some procedural resemblances can be drown (instead, duality as a cognitive "mechanism" does prevent this possibility). Notwithstanding, let us stress the difference between semantic features on the one hand and the information music can transmit. In other words, Hockett's duality, if strictly assumed, cannot be active part of musical outcomes, due to the lack of linguistic meaning. However, if *duality* is considered as a property of the signal produced by a mechanism that encodes bits of information (for example, *motives*) into signals – here, arrays of notes and silences –, this does open the door to the consideration that the same combinatorial mechanism is also working behind music, since its putatively architectural procedures can be argued to be involved in both lexical units and in musical units. It is to this extent only, that duality could be an effect detectable in other cognitive elements beyond the linguistic phenomenon, like music – thus, understanding music as a *human communicative subsystem*, in Hockett's terms.

Finally, let us apply the notion of duality to a last case. We think it is impossible to close a discussion like the present one, without making mention to the first biological system of transmission of information: the deoxyribonucleic acid, or DNA. Almost forty years after Simon's "silent revolution", William L. Abler has contributed to the issue with his proposal of the "principle of self-diversifying systems", which seems to be shared by all particulate systems like language, maths or DNA[37] (Abler 1989, 1997, 2006): "the systems which make infinite use of finite media whose synthesis creates something that is not present *per se* in any of the associated constituents are formed on the basis of underlying particles" (Abler, 1989: 12). Both Simon (1962) and Abler (1989) focused their attention to the particularities of the systems, which reach high levels of complexity from discrete units. Abler was in particular who observed that it cannot be just happenstance that language and such systems share the same basic properties. These properties are in the nature of systems themselves. This is true regarding the context of complex systems. Previously, both Jackobson (1973) and Marcus (1995) had already seen architectural similarities between DNA and language. Marcus has pointed out the fact that DNA combinations share with language the duality of patterning. Is it really duality? DNA, like language, has a limited number of four amino acids that are the primitive elements. Alone, an amino acid cannot transmit any information to the transcriptome. It must combine with other two amino acids. It is then that the triplet has "meaning" and is interpreted adequately.

[37] An author strongly vindicated by Studdert-Kennedy (1998).

There are some differences, however, regarding language. For example, DNA exhausts all the possibilities. Since the only possibility is a triplet, and there are 4 primitives, there are 64 possible combinations, all of them interpretable by the system. Thus, it is a closed system that makes use of duality in order to configure its messages. This important issue deserves more attention and much could be said about it, though it goes far beyond the scope of this work. The most important is that our notion of duality can successfully be applied outside human language, because it is a property of the signal, and hence we count on a concept that is not stipulative for human language, preventing *per se* any other comparison.

Conclusions

After a careful analysis of the notion of duality according to Hockett, we have verified that it has been often misunderstood through decades. We have shown that duality is a concept that pretends to describe a universal feature of all human languages, sign languages included. However, the peculiarities of duality make this notion more suitable for externalism than for an internalistic approach to language. We have also shown the problems this notion has for its integration into the minimalist perspective of language. After rejecting the confusion between duality and recursion, we have explored two possible models. And two possible interpretations: the first considers duality a mechanism. The second considers duality a mathematical property of the signal that emerges when a combinatorial systems needs to create meaningful units (pleremes) from meaningless primitives (cenemes). Thus, we conclude that its theoretical inclusion is possible if duality is seen as an emergent property of the public signal, a side-effect of the combinatorial mechanism. We suggest that unbound recursion makes possible the attachment of mental lexical items to an unbound though finite set of arbitrary arrays of phonemes. The outcomes of this union process constitute the public lexicon. Our approach takes into account that phonology is substance-free, and that this makes PHON independent of the modality (oral or signed). The model B we adhere maintains separated the internal *lexicalized items* from the public lexicon. We contend that it is in the context of latter where duality becomes relevant. Finally we would like to highlight that our proposal of duality makes it a suitable concept that can be applied to cross-field studies that deal with communication systems which are able to create from meaningless primitive units larger meaningful units.

4.2 Campbell's monkeys alarm calls are not morpheme-based

This work has been benefited from interesting questions of the audience at the Graduate workshop on biolinguistics within the 19th Conference of Student Organization of Linguistics in Europe at the University of Groningen (2011, January 5-8).

This work has been accepted as paper and will appear, co-authored with Antoni Gomila, in the World Scientific's next volume of the proceedings of the Evolution of Language Conference (EVOLANG9) in 2012, at the papers section.

V

CONCLUSIONS

5. Conclusions

Through these pages I have carried out one the task of building bridges between different areas of science, all of them useful to cover certain aspects of language. Language as a cognitive capacity is a kind of element that will develop in a human brain if it is in normal conditions and receives the proper stimuli. The development of language is tied to the development of syntax. Interestingly, this seems not be the case of speech.

My research on the available, though unlinked, pieces of information about speech suggests that the lack of speech no longer can be used as a strong argument against the existence of language in non-human hominids. Of course, it could be that, even after gathering so many and diverse evidences, the Neandertal man was unable of producing speech like us. However, let me insist, we will need to find stronger evidence, because until now the arguments against it, are weak in comparison to the amount of information suggesting the contrary. This should be surprising, given the fact that since many years there is the suspicion that the sensory-motor interface is quite old, evolutionary speaking. Chomsky has said that it is an ancient module doing the best it can in order to externalize highly complex mental structures. Thus, after all, if it so old as suspected, why could not Neandertals have a similar capacity for speech, if the two species are so close on each other? It is true that the argument of hybridization cannot be used any time someone presents an argument against Neandertal speech. Nevertheless, it can also not be forgotten. Important is to keep in mind that the ability for speech does not automatically enable this species for the use of language.

I have shown that there are evidences enough pointing to the complexity that governs language. There are many interesting aspects that can be related to it, like non linguistic behavior. It is perhaps a good line of research, in order to investigate further why these great differences between species do exist in the archaeological record; why, despite hybridization, not all pieces of the puzzle fit together; why Neandertals disappeared. I do not think that all these questions can be boiled down to language. If language is, after all, a kind of side effect, the answer could be, so to speak, the typology of cognition each species had. This would mean that language is a collateral effect on the capacity of communication, and that the real change has happened in the mind, in the way the brain relates concepts, and creates conceptual structures. I think we are still far of proving something like this, but these are promising questions. That *H. sapiens* has de tendency

for developing language, is not something new. The syntactic analysis of the children's speech represented through networks is just another piece of evidence supporting this old suspicion. The three children have develop syntax following similar patterns, regardless which first language they were acquiring. What was a pioneer work on a language, using a new methodology for language acquisition studies, has been replicated in three more children, acquiring three different languages. Some methodological questions have been answered, like the suitability of these tools for this kind of research, or the quality of the data base, naïve at regarding our purposes and aims. The results suggest that children, after a linear pattern of syntactic development, undergo an abrupt change that yields qualitative differences in the rating of syntactic development. After a specific point of brain maturity, the growth of syntax no longer follows a linear pattern. Of course, many questions rise too. I think that these results can be reinforced in a future, if non Indo-European languages are put to the test.

An interesting aspect of this analysis is that if we are on the right track and syntax is ultimately based on the iterative operation merge, this could be the kernel of the differences between the to species. As I said in the introduction, real interdisciplinary research is needed in order to get new perspectives able to to provide answers for old questions.

Another interesting issue I have developed here, on the notion of duality of patterning, links together many different fields that have in common the interest for communication. I think the the notion of duality as I have presented it, following Hockett and Fortuny, can be useful in future research and can be applied to areas that, at first glance, have nothing to do with human language, but that share a common quality like duality. Whatever the system for information transference we are talking about, if it has duality, it is worth to be compared with language, in order to check the behavior of duality in that system, and the differences with language regarding information transference.

I think that usefulness of this thesis is that it has deepen in the knowledge we humans already had. By bridging different areas of research, some of them traditionally unconnected, we have got new knowledge about Neandertals and ourselves; about the notion of recursion and its insertion in the evolutionary studies. From an international and frequently visited database of linguistic corpora, we have been able to extract interesting information regarding the patterns of syntactic development. By crossing the traditional frontiers of linguistics, I have imported robust notions from Information Theory to the current discussion on human language.

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