Why /i a u/ and /B D G/ ? Or why such an extremist evolutionary recurring trend in speech sound systems?

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In the world language databases (Maddieson, 1986), /B D G/ are the most prevalent places for consonants, as are the point vowels /i a u/. Jakobson, Fant and Halle (1952) conceived acoustically these places in parallel with the vowels, as a triangular representation, until Chomsky and Halle (1968) switched to articulatory features. Lindblom's (1986) and our endeavor rests on an acoustic space for vowel systems computational prediction. Up to recently it was not conceived of consonant systems (say syllable onsets *) as implicating the same principles as for vowels. It is now possible to show that /i a u/ for vowels and /B D G/ for consonants follow the same maximal dispersion trend. Labial, coronal and dorsal onsets are optimally distant auditorily, while other features like retroflexion or pharyngealization use only secondary dimensions (as e.g. for vowels nasality and length). One must keep in mind that there is no in principle reason for not having less extreme exemplars of vowel types in very small numbered systems, where the auditory distinctiveness has not need to keep such extreme vowels apart. But a spacing like /e a o/ is not what is generally observed for inventories as small as 3 vowels: /i a u/ instead. It seems however that a significant proportion of Australian languages do not display such extreme prototypes (Butcher 1994). But this question can be reconsidered in the light of old and new observations: that is by factoring out coronal consonant secondary types (retroflexion...) coarticulatory influence; and by taking into account the possibility of producing occurrences of extreme types in informational prosodic conditions (Fletcher, Butcher, 2003). The answer to this recurring extreme trend lies in our Dispersion-Focalization Theory (Schwartz et al., 1997). DFT allows to predict vowel systems thanks to a competition between two perceptual costs: (i) dispersion based on inter-vowel distances, (ii) local focalization based on intra-vowel spectral salience related to formants proximity. The first one is related to the global structure of the system and the second to the internal structure of each vowel element. The DFT predictions fit quite well with the phonological inventories being compatible with preferred 3-to-7 vowels systems, and also with the possible variants in the systems and in which order they can appear. In DFT /i a u/ are focal vowels, that is objects which are not only far away but also intrinsically well formed perceptually and memorily, whatever the articulatory costs for maintaining easy or difficult controls, reputedly easy for /a/ and /u/, and typically difficult for /i/. The same framework has been demonstrated to work for consonants (Abry, 2003), in a dynamic F2-F3 Consonant-Place-Space (CPS) in continuity with the classical Vowel-Position-Space (VPS). What could then be the differentiation process, i.e. the genesis of the workspaces for consonants and vowels in this common framework of auditory coordinates? We propose a developmental scenario for speech sound systems ontogenesis - from canonical babbling (MacNeilage, Davis, 2001) to the emergence of coarticulation - suggesting implications for the phylogenesis of speech.

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* In a first generalisation, considering that CV is the universal syllabic frame, consonants are simply considered here as syllable onsets

and vowels as syllable climaxes in the speech flow.

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The impact of population dynamics on language evolution

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Language is culturally transmitted — children learn their language on the basis of the observed linguistic behaviour of others. A recent trend has been to explain the structural properties of language in terms of adaptation by language in response to pressures acting on it during its cultural transmission. Using this approach, properties of language such as recursion (Kirby 2002) and compositionality (Smith *et al.* forthcoming) have been shown to be adaptations which help language survive the repeated cycle of production and learning. A particular feature of this research has been the extensive use of computational models.

These models suffer from an impoverished treatment of population dynamics. Population sizes are severely restricted, with populations consisting of a single individual at each generation being common. Within-generation horizontal transmission is typically ruled out. Population turnover is also highly simplified, with populations usually being modelled as a series of discrete, non-overlapping generations.

This simplified treatment of population dynamics is rather unsatisfactory, particularly given the importance of factors such as population structure and demography in language evolution in the real world. In surveys of the importance of population factors in language birth and language change, Ragir (2002) and Kerswill & Williams (2000) highlight three aspects of population dynamics which impact on linguistic structure: languages are more likely to acquire complex linguistic features, or to change in ways which preserve such features, when 1) populations are large; 2) the proportion of adults to children is low; 3) there is a high degree of child-child contact.

An important next step for models of the cultural evolution of language is therefore to develop more sophisticated treatments of population dynamics, in order to explore and ultimately understand why population factors play such an important role in language birth and change. I will present an extension to Kirby's (2002) model of the cultural evolution of recursively compositional syntax, which is designed to allow a treatment of varied population dynamics. Experiments carried out using this model show that the emergence of structured languages is dependent on three factors: 1) learners must acquire their language based on observation of a small number of cultural parents; 2) the optimal number of cultural parents depends on overall population size, with larger populations requiring smaller numbers of cultural parents; 3) learners must not learn from other learners — even small amounts of horizontal transmission impede the evolution of linguistic structure.

The extended version of Kirby's Iterated Learning Model therefore makes a series of incorrect predictions — the results of the experiments carried out using this model suggest that structured languages will only emerge when populations are small, the proportion of adults to children is high and there is little child-child contact. These predictions are exactly the opposite of the real-world data summarised by Ragir and Kerswill & Williams. This extension to a well-established model shows that a richer treatment of population dynamics is a challenging and important future development in the computational modelling of the cultural evolution of language, and one which may not prove straightforward.

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Lexicon acquisition in an uncertain world

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One of the distinctive features of human language is its use of arbitrary symbols to convey meanings from one person to another. In this paper, we focus on the problem, famously described by Quine (1960), of how learners learn the meanings of words, when they cannot receive any explicit information about the association between the two elements. Without such information, learners must rely on some external information to provide clues to the intended meaning, such as the pragmatic context in which the word is presented.

We have previously developed a model of meaning creation and inference in which agents use a Bayesian learning strategy to learn the meanings of words by disambiguating potential meanings through the presentation of words in multiple contexts (Vogt, 2000; Smith, 2001); we now formalise this computational model so that we can make accurate predictions of the likely outcomes of future experiments. In particular, we present a mathematical model for predicting the time needed to learn an associative lexicon of a given size and a given level of referential uncertainty, based on the cross-situational statistical learning used in the computational model.

We quantify the number of communicative interactions which are necessary for one agent to learn a lexicon from another, given the degree of uncertainty, and show that our mathematical model compares well to our computational simulations of lexicon acquisition under similar conditions. Furthermore, the model predicts that successful learning will take place even with surprisingly large levels of uncertainty in the model.

We go on to compare the model to other cross-situational learning models (e.g. Siskind, 1996), and show how the model can be extended to take account of more realistic Zipfian distributions of word frequency. This allows us to explore whether the model can provide helpful predictions about the conditions under which children learn language. With such distributions, learning is clearly much harder, as it takes much longer for us to be sure that the learner has been exposed to the whole lexicon, and so the level of uncertainty must be reduced relative to the uniform model. Many psycholinguistic biases, indeed, have been proposed to account for this necessary reduction of referential uncertainty, and thereby for the speed with which children acquire their lexicons (Bloom, 2000); the model presented here will also provide a formal mechanism for exploring the relative effectiveness of these hypotheses.

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Developing Grammars in Embodied Situated Language Games.

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The paper further explores the hypothesis that grammatical constructions primarily arise because a speaker seeks to maximise the chance of communicative success and the expressive power of her utterances. New lexical or grammatical constructions are introduced when parts of the meaning are not yet covered or when the available linguistic material may lead to a failure or a risk of failure in communication. When verbal interactions are grounded and situated, the hearer has a good chance to be able to infer the meaning of novel expressions, reconstruct the underlying constructions, and integrate them into her own repertoire.

The paper also explores the hypothesis that meanings and their expression co-evolve. New meanings arise because the speaker needs to make distinctions which were not made before. These distinctions become lexicalised and grammaticalised to achieve success in communication. The hearer acquires new meanings by reconstructing these distinctions while trying to create hypotheses for the meaning of unknown grammatical constructions.

These hypotheses sound entirely reasonable but the big challenge is to work them out in technical detail and show that their cummulative effect leads to languages with natural language-like properties.

We have been constructing various computer simulations trying to do this, and engaged in experiments with robotic agents playing situated language games.

Our focus has specifically been on how grammars for case and tense could self-develop in a group of autonomous embodied agents. In the present paper, I focus on the core of the cognitive mechanisms responsible for grammatical development in these experiments: (1) a mechanism used by the speaker for detecting potential uncertainty in communication, (2) a mechanism used by the speaker for inventing a new grammatical construction to alleviate such an uncertainty,)3= a mechanism used by the hearer to detect the meaning of a new grammatical construction introduced by the speaker. The main point of the paper is that the mechanisms are generic and generalise across the domains of case and tense.

Analysing the analytic: problems with holistic theories of the evolution of syntax

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Until relatively recently, most researchers saw syntax as evolving from an earlier stage with only single words, strung randomly together in a structureless protolanguage. However, other recent work proposes that words are not primary, but emerge from longer, entirely arbitrary strings of sounds, via fractionation (Arbib 2002, 2003). In this analytic approach (Wray 2000, 2002) protolanguage consists of a fixed set of formulaic utterances, used 'for getting things done and for preserving social stability' (Wray 2000). 'Holistic' utterances are unanalysed wholes, with no consistent regularities. For instance, Wray suggests such strings as _tebima_ 'give that to her' and _kumapi_ 'share this with her'. In time, unanalysed material is segmented into meaningful units, when, by chance, phonetically similar substrings occur in several utterances, and can be imbued with a common meaning. In the examples above, _ma_ occurs in both strings, and the meaning 'her' occurs in both formulaic utterances, so _ma_ comes to mean 'her'.

In this paper, I dissect the analytic view of early protolanguage, and examine a number of serious flaws in the arguments proposed for it. The main problems are summarized in (1)-(5):

1. Logically, similar substrings must often occur in two (or more) utterances which do NOT share any common elements of meaning at least as many times as they occur in two utterances which DO share semantic elements. For instance, a string _mabali_ also contains the _ma_ sequence, but means 'put that rock down!'. What ensures that _ma_ gets associated with 'her'? Repeated usage alone can't establish all and only the right 'regularities' in the proto-lexicon.

2. Wray suggests that holistic protolanguage is not referential. In fact, it is entirely referential, but all the utterances refer to whole complex events. Whereas vocabulary can be stored by pairing a concept with the arbitrary sound string used to denote it, holistic utterances must be stored by memorizing each complex event and learning which unanalysable string is appropriate at each event. This task is harder, not simpler, than learning words as symbols, and therefore less suitable for an early protolanguage scenario.

3. Although formulaic utterances are common in modern language, and often opaque in their syntax and/or semantics - 'the more, the merrier'; 'he bought a pig in a poke' - they rarely contravene existing syntactic rules. So, an idiom in English could not have OSV word order. This suggests that formulaic utterances are parasitic on existing syntax, emerging from earlier states of syntax via well-known processes (such as grammaticalization). Formulae come from existing grammar, rather than providing tailor-made models for syntax.

4. Wray and Arbib liken formulaic utterances to the 'calls' of primate communication. But primate vocalization is handled by different parts of the brain than human language (Myers 1976, Bradshaw & Rogers 1992), and the homologues of Wernicke's and Broca's areas are not used for vocalization. Thus, the continuity problem persists: holistic calls are not the precursor to language.

5. Words will never appear out of formulae unless the hominids using holistic protolanguage have a) the motor control required to produce recognizable substrings and b) the neural capacity to recognize phonetic strings. But the holistic approach endows these speakers with a greater ability in both areas than would be needed for one-by-one words: the formulae are necessarily longer strings (otherwise they couldn't be broken down) and the speakers need to recognize and utilize subparts of these longer strings. How could this ability exist at the pre-syntactic stage?

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Language Emergence: a Self-Organized Model using Indirect Meaning Transference

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Abstract

With the introduction of computational modeling into linguistic study, many plausible models (Ke et al 2002; Kirby 1998, 2002; Batali 1998; Cangelosi 2002) of communication among a group of homogeneous agents have been presented, which investigate the emergence of both unstructured and structured utterances, and are based on both learning and evolutionary mechanisms. However, the use of direct meaning transference in supervised learning, ignoring the evolution of syntax, and not studying the effect of social structure on language acquisition all limit the authenticity of these models. Based on Wray's emergent scenario (Wray, 2002), we assume that language emerged during an iterative process of decomposition, combination and cognizing the environment. In this paper, a computational model on language emergence, following this view, is presented to address limitations stated above.

In this model, co-evolution and convergence of lexicon and simple syntax (word order) at the protolanguage level and a transition from holistic utterances without internal structure to compositional language with a dominant word order are driven by strategies of self-organization (e.g., rule activation, rule-based decision-making and competition inspired by Classifier Systems (Holland 2001)). Indirect meaning transference, in which interaction of linguistic and non-linguistic information (cues, meanings extracted from environmental information) determines meaning interpretation, together with a primitive feedback mechanism without direct meaning checking are implemented. The cues are not necessarily always reliable; nevertheless, the language acquired in this model can still be used to robustly express meanings not present in the immediate environment of the agents (displacement) and to accurately interpret the meanings of utterances even under wrong cues.

Due to the lack of explicit access to other agents' languages and agents' use of free search to detect recurrent patterns, homophony and synonymy are inevitable in this model. With unreliable cues, at the protolanguage level, homophone avoidance might be necessary to avoid ambiguity in communication during the transition from a holistic signalling system to a compositional language.

Exploratory research on the effect of social structure on language acquisition, based on network theory, is introduced. A social structure with popular agent(s), common in primate societies and which might have been common in early human societies as well as, is studied. In such social structure, it seems that there is an optimal popularity rate of the popular agent for a language to develop effectively in the population. Further study of social structure using more complex network structures (e.g., scale-free network, small world network) is a promising direction that we expect to make progress in during the coming months.

Finally, other promising future work, such as introducing heterogeneity in agents' abilities in language processing, and simulating

communications among more than 2 agents, is identified.

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Non-verbal Vocalisations - the Case of Laughter

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The most frequently used form of communication between humans is conversation consisting of both speech as verbal vocalisation and non-verbal vocalisations. The question addressed here is how non-verbal vocalisation such as laughter differs from speech articulation. Data inspections to be presented here give an idea how laughter is integrated in every-day speech as a unique signalling system in non-verbal as well as verbal vocalisations.

In dialogues, many features are transmitted by paralinguistic vocal parameters such as pitch range, intensity and speech tempo. In addition to these prosodic properties, which modify the articulation of verbal material, there are the less well-studied non-verbal vocalisations. These include e.g. backchannel-utterances (indispensible for dialogues), filled pauses (frequent in spontaneous speech), and affective interjective calls which are produced by speakers and hearers for attitudinal and emotional signalling.

The observation of laughter-like calls in apes and monkeys (e.g. Preuschoft, 1992) led to a debate whether only humans laugh. In contrast to non-human primates, the situations in which humans laugh during speech show a great range: mirth and joy, humour, malice, embarrassment, and even despair. Likewise, human laughter does not show just one form but a great repertoire of different kinds of laughter. Bachorowski et al. (2001), e.g., divide laughter in song-like, snort-like and grunt-like types. Further forms are speech-laughs (Nwokah et al., 1999) which are produced simultaneously to speech. Trouvain (2001) found in a German dialogue database that most laughing events occur during articulation of lexical items, not as vocalisations of their own.

However, the production of laughter is clearly distinct from speech production. Although the consonant-vowel pattern in laughter (cf. lexicalised "haha", "ahah", "xaxa") superficially resembles speech, the control for respiration, phonation and articulation is much simpler. A typical voiced laugh combines a simple exhalation muscle command with a "program" for voiced-unvoiced alternations. This pattern is highly rhythmic but with a timing pattern completely different to phonologically comparable ones in speech. In contrast, speech-laughs are nested in the articulatory processes of segments: the stronger aspiration typically occurs in aspirated parts just as the voice vibrato appears in voiced segment portions.

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"The appearance of design in grammatical universals as evidence of adaptation for non-communicative functions"

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Many authors (e.g., Hauser, Chomsky & Fitch, 2002) have expressed doubts that the evolution of grammatical universals can be exclusively explained in terms of adaptation, noting that many such constraints have a "tenuous connection to communicative efficacy" (p.1574), but even if we assume that a given universal of grammar is unrelated to communicative efficacy, this does not preclude it from being an adaptation for non-communicative functions. For instance, a universal could be selected for improving language learnability or for its effects on reducing the costs associated with the language faculty in terms of metabolic energy or other neural resources. The present study examines one such hypothesis relating to closed-class functional categories (i.e., grammatical words and inflections) and concludes that since they appear to be extremely well designed to economise the lexicon, they are probably worthy of being labelled an adaptation.

By encapsulating lexical categories, functional projections can mediate grammatical relations so that lexical entries for lexical categories can remain extremely simple in terms of formal features. For instance, learning that a noun is associated with determiners allows a noun, encapsulated in a DP, to be used as either the subject or object of a sentence or as the object of a preposition and so forth. The language learner does not have to learn all of the contexts in which a new noun can be used because this information is encoded in the few words that constitute the closed class of determiners. So long as the proportion of closed-class items in the lexicon is small relative to the open-class items, the additional representational complexity that they require will be more than offset by the reduction in complexity of the very many more open-class items. This is a very economical way to minimise the storage requirements of the lexicon, and would presumably translate into savings of metabolic and neural resources -- savings which we can expect natural selection to favour. We should also expect a simpler lexicon to have fairly obvious advantages in terms of learnability.

Examples of functional projections will be discussed in support of these claims and further applied to illustrate how constraints like the case filter and the extended projection principle are expected consequences of an optimised lexicon, thereby relating these specific constraints and their effects to natural selection for the first time. The role of iterated learning processes (Kirby & Hurford, 2002) in the evolution of functional projections will also be discussed and related to the proposal by Fukui (1995) that syntactic parameters are limited to formal features of functional categories.

Acknowledgement: This research was supported by EPSRC grant GR/N01118

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Evolutionary games explain efficient language organization

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Recently, evolutionary game theory (EGT) has been used (e.g. Nowak) to study the emergence of *syntactic* (e.g. *compositionality*) and *semantic* (lexical entries) features of natural language. Here it is used to explain *pragmatic* linguistic principles.

Consider the case where two meanings m_1 and m_2 can be expressed by two linguistic signals s_1 and s_2. In principle this gives rise to two possible codings: $\{\langle m_1, s_1\rangle, \langle m_2, s_2\rangle\}$ and $\{\langle m_1, s_2\rangle, \langle m_2, s_1\rangle\}$. In many communicative situations, however, the underspecification does not really exist, and is resolved (e.g. by the use of pronouns) due to the general pragmatic principle that a lighter form will be interpreted by a more salient, or stereotypical, meaning. If we can explain this principle, we can also explain why language is organized so efficiently. To do so, however, we need, first, to explain why one way of resolving the underspecification is more natural than the other, and second, to show why underspecification of meaning is useful in the first place.

To explain both, we will make use of *signaling games* as introduced by David Lewis (1969) to account for linguistic conventions, and developed further in economics and theoretical biology. In this framework, signals have an underspecified meaning, and the actual interpretation the signals receive depend on the equilibria of sender and receiver strategy combinations of such games. Recently, these games have been looked upon from an *evolutionary* point of view to study the evolution of language. According to it, a coding (or signaling) convention can arise according to which signal s means m if and only if the pair $\langle s, m\rangle$ is part of an *evolutionary stable strategy* (ESS). Unfortunately, one can show (Wärneryd, 1993) that the ESSs of signaling games always give rise to 1-1 mappings between signals and meanings. But this predicts false: underspecification (or homonymy) of meaning is predicted not to exist, though in fact it is the rule rather than the exception in natural languages. So, if evolutionary game theory is to be a useful tool to investigate the evolution of language, it better is able to explain why and how we make use of expressions with incompletely specified conventional meanings.

It is. The solution is based on three ideas. First, and obviously: *underspecification* makes sense because speaker and hearer share a common *context* which helps resolving what is intended. We will show that languages that make 'smart' use of contexts are evolutionary stable. However, they are not the only ones. To select the 'smart' ones, we use a second idea and take into account (i) the *costs* of sending signals, and (ii) the *probabilities* of the meanings. As a result, of all evolutionary stable strategies, only the 'smart' ones are Pareto optimal. Still, standard evolutionary game theory gives no reason why only those should emerge. As the third idea, I propose two possible solutions: *correlation* (or clustering) and *mutation*. The first assumes that agents tend to speak more with others that use similar strategies (languages). One can show that assuming correlation in EGT gives rise to the emergence of strategies with the highest expected utility, are Pareto optimal. The second proposal assumes that the evolutionary transition from one generation to the next is *stochastic* in nature. One natural way to think of this is as being due to imperfect language acquisition. General game theoretical results (e.g. Young, 1990) show that such an evolutionary process gives rise to risk-dominant equilibria, which in cooperative games are equal to the Pareto optimal ones.

If time permits, I will discuss the naturalness of those two solutions and give evolutionary motivations of other pragmatic interpretation principles (such as the Gricean maxims of quantity and quality) as well.

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How ecological regularities can shape linguistic structures

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A hot topic in language evolution and computation is modelling the emergence of compositional structures in language, see, e.g., (Batali 1998, Kirby 2001). However, these models typically take a compositional structure of the meaning space for granted. Moreover, these models assume a predefined meaning space and all the agents in these models have to do is develop a syntactic language. I agree that this is important research from which we learn a lot, but these studies are bound to overlook crucial aspects of symbol grounding, at least to some extent.

One trap that may appear is that one overlooks the possiblity that agents can exploit the interaction with the environment. In this paper I will illustrate, using computational modelling, how agents can exploit regularities of their ecological niche to shape the compositional structures they evolve culturally in language. In this model, agents develop a compositional structure based on a number of perceptual features (3 features to represent colour and 1 to represent shape). The implicit goal is to develop a compositional language in which sentences are expressed by two components. Initially, the agents have no clue which features belong to colour and which to shape. Naturally, we hope to find that the emergent components distinguish between colours and shapes.

The model combines the principles behind the Talking Heads experiment (Steels et al. 2002) with the iterated learning model as was implemented in (Kirby 2001), and is described in detail elsewhere (Vogt 2003). In the iterated learning model, language evolves by iterating a cycle in which learners learn language by observing the linguistic behaviour of adults, until the adults `die', learners become adults and new learners enter the population. When learners enter the population, they have no categories (meanings), words or grammar; these develop during their `lifetime'.

The environment of the agents contains a given number of distinctive shapes, which can have a fixed number of different colours. Initially, perceptual features are categorised holistically, i.e. by forming categories as regions in a conceptual space that covers all quality dimensions (perceptual feature dimensions). By finding regularities in the categories that the agents form on different occassions, the agents are able to group those quality dimensions that have similar values. Syntactic structures emerge based on a similar heuristic, which was adapted from Kirby's (2001) model. Combining the two mechanisms, the model exploits a co-development of semantic and syntactic structres. The resulting induction mechanisms are similar to those that have recently been proposed as a model for human language acquisition (Tomasello 2000).

Simulations are presented that show how a compositional language can emerge from scratch. Moreover, the languages that emerge typically reflect the regularities found in the perceptual features agents detect when seeing their environment, and contains linguistic structures concerning colours and shapes both at the syntactic and semantic level.

Summarising, the simulations show that a compositional language can evolve through a combination of cultural evolution (at the syntactic level), simple induction mechanisms and the interaction of agents with their environment.

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Generalisation as a bias toward the emergence of Zipf's law

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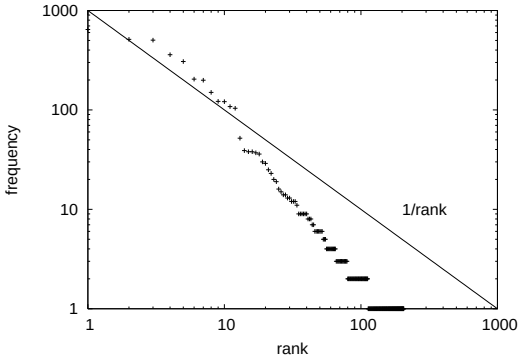
All human languages show the characteristics of Zipf's law (Zipf, 1949). This law is the observation that the frequency with which words occur decays as a power law of their rank. If words are decreasingly ordered based on their frequency, the frequency $f(k)$ of a word with rank k is given by $f(k) \propto k^{-\alpha}$, where $\alpha \approx 1$. Zipf explains the emergence of his law using the principle of least effort; speakers want to minimise the effort for producing utterances, and hearers want to minimise the effort of understanding them. This principle seems to hold at various levels, such as the phonological and the lexical level (Ferrer i Cancho and Solé, 2003).

In this paper, I show how Zipf's law can emerge through a tendency to minimise the effort in categorising perceptual features. I do not claim that this is the only bias at work; other biases, such as influences taken from the environment and discourse models, have shown a tendency toward Zipfian distributions as well (Tullo and Hurford, 2003). However, the principle of least effort – on which the findings in this paper are based – appears to be sound (Ferrer i Cancho and Solé, 2003).

The data presented in this paper are drawn from robotic experiments that have been carried out at the end of the past century, e.g., (Vogt, 2000). In these experiments, two mobile robots developed a shared lexicon from scratch of which the words' meanings were grounded by the robots' interactions with the environment. The experiments were based on adaptive language games (Steels, 1996) in which a speaker produces an utterance, which the hearer tries to interpret. During the experiments, the robots developed categories (meanings) in a number of conceptual spaces that had various levels of granularity, but were spanned by the same quality dimensions (perceptual feature dimensions). Thus, sparsely filled conceptual spaces contained more general categories than densely filled ones. In the language games, the robots first tried to categorise the perceptual features in the sparsely filled spaces. When they failed, they incrementally tried the more specialised spaces. This way, the robots preferred to communicate about more general concepts than less general ones. The main reason for this design was to minimise computational complexity (finding categories in densely filled spaces is computationally expensive).



freq.	≥ 50	≥ 10	≥ 5	≥ 2	$= 1$
%	100	67	38	26	19
layer	1.00	1.86	2.57	3.21	2.87

Recent (re)inspection of the data revealed the emergence of a Zipfian distribution in the relation between word-frequencies and their rank (see figure). Closer inspection even showed that word-meanings about general categories appeared more frequently than those about specialised categories (see % row in table, which gives the percentages of word-meanings of which the meanings are at the most general layer). Categories emerged at five different layers of varying granularity, the final row of the table shows the average layer with respect to the frequencies of word-meanings (layer 1 being the most general).

Given these results, I conclude that having a tendency to minimise the effort by trying to communicate using the most general meaning in a situation, has led for these robotic experiments to the emergence of a Zipfian distribution in word-meaning rankings. Hence, I hypothesise that a generalisation bias – as a strategy imposed by the principle of least effort – leads, among other biases, to a Zipfian distribution in natural languages.

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Modelling type-denoting concepts and words in a simulation of vocabulary development

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Steels (2000) proposes a mechanism by which a community of agents is able to negotiate a common vocabulary for referring to objects in their environment, using two simple games. In a 'discrimination game', an agent equipped with a set of simple sensory channels attempts to distinguish a target from a set of context objects. If it cannot do so, it subdivides one of its channels to make discrimination more likely in future. In a 'language game', a speaker agent identifies an object in the world, and consults a lexicon of mappings from object concepts to words to generate a word for this object, which is then sent to a hearer agent. The hearer uses its own lexicon to attempt to identify the object in question. If successful, the word-concept mapping is reinforced for both speaker and hearer; if not, the speaker indicates the intended object explicitly. Using these games, a group of agents can successfully develop a shared vocabulary.

However, it is possible that the success of Steels' system is an artefact of the highly artificial classification and word-learning mechanisms which its agents use. The discrimination games make no reference to current biological theories of perception and discrimination, and the language games make no reference to psychological theories of vocabulary acquisition. The present paper describes a Steels-like system in which agents have more psychologically realistic categorisation and word-learning methods.

One problem with Steels' discrimination games is that they are designed to identify objects in the environment as tokens, rather than types. Biological categorisation systems, on the other hand, break the world up into types of object for which the same set of behaviours is appropriate (see e.g. Rosch et al., 1976). To address this issue, an alternative to discrimination games was implemented, in which agents classify objects as types rather than tokens, using a self-organising map (Kohonen, 1982). We defined a set of objects which varied along a set of independent dimensions, and which could be made to cluster in different ways. An agent using a self-organising map is able to learn types which correspond to these clusters, and to recognise token objects as belonging to these types. We also defined a type-based analogue of Steels' language games, and showed that the new games allow a shared vocabulary to emerge. (Interestingly, in a parallel with Quine's (1977) observations about word learning and natural kinds, a shared vocabulary only emerges if there are genuine clusters of objects in the world.)

A second, separate problem with Steels' system is with the language games themselves. In Steels' language games, the speaker only points to the target object if the hearer has not identified it correctly; this behaviour is not attested in studies on infant vocabulary acquisition in humans. The two dominant models of infant vocabulary acquisition are the joint-attention model of Baldwin (Baldwin, 1995) and the statistical learning model (see e.g. Saffran et al., 1996). We developed a formal model of each of these approaches, and implemented each model in our agent-based simulation. Again, both models allow the development of a shared vocabulary among agents.

The main conclusion of this work is that Steels' system can be successfully reimplemented using more psychologically realistic object classification and word-learning methods. In addition, by focussing on type-denoting terms, the new implementation provides a sounder basis for studying the evolutionary emergence of real natural language parts of speech such as 'noun' and 'adjective'.

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Some prerequisites for the emergence of phonological compositionality

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This paper will investigate the problem of prerequisites for the emergence of the compositional principle in the phylogeny of phonology. A number of researchers have addressed the issue, including, in particular Lindblom, Studdert-Kennedy and MacNeilage. One common thread in their proposals is the role attributed to "pressure for a larger lexicon" in the development of phonological compositionality.

The present paper will argue that "pressure for a larger lexicon" is not the best candidate for the main driving force behind the process (cf. e.g. Carstairs-McCarthy 1998). Instead, it will propose that expansion of the "lexicon" was the result rather than cause of the gradually increasing availability of recombinable articulations. Some arguments against the "pressure for lexicon" scenario include the following:

Ancestral species of Homo probably had at their disposal a functioning system of vocal communication. To be selected, the larger lexicon would have to confer a significant advantage over the old system. But for recombinable units to be extracted from larger articulations, such units must have been present in them in the first place. If these "calls" had been used for communicative purposes, the discriminatory power of the "old system" would have been large enough for a pressure for a larger lexicon to become questionable as a motivation for phonological compositionality, requiring a saltationist scenario in which the new development would have had to be quick, abrupt and dramatic. Additionally, such an approach suggests a teleological goal in the evolutionary development of early Homo communication systems.

The proposed alternative scenario will be as follows:

(1) Progressive changes in the anatomy of the upper vocal tract and its innervation (cf. Demolin 2003) led to an increased availability of articulations (consonant-like in particular).
(2) Self-organisation of these articulations into a repertoire of recombinable units may have started in younger members of the population, especially in vocal play.
(3) Iterative learning (cf. Hurford and Kirby) and imitation may have led to social spread of articulations offering robust acoustic effects.
(4) With time, these may have come to be used in communicative interactions, with the first step possibly being what might be termed "signature calls" (cf. Ujhelyi 1998).

This scenario has at least two interesting aspects. Firstly, it seems that the process may have been strongly dependent on the appearance of an increased number of stable consonant-like articulations, as such articulations, in addition to acoustic feedback (useful for imitation), also offer good orosensory feedback (useful for exploring one's own vocal capabilities, cf. Vihman's Articulatory Filter, and in consolidating and stabilising the articulations, cf. Perkell et al. 2000). Secondly, the role of young "speakers" cannot be overestimated, as the youngest members of proto-linguistic populations may have started the process by not only discovering their own articulatory capacities but also by progressively dissecting the allegedly holistic utterances found in the ambient communication system.

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The consequences of talking to strangers: sociocultural influences on the lexical unit

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We propose to reconcile a number of contradictory proposals about language and how it evolved, by demonstrating that they are consistent with a model featuring flexible lexical storage. One debate concerns whether any language can be (fully) characterised in terms of "words and computational procedures ('rules') for constructing expressions from them" (Hauser, Chomsky & Fitch 2002:1576), or whether words and rules are more a feature of how we describe language when we externalise it than of how we actually process it (Grace 1998:69f). A second thread relates to longstanding evidence that languages have fundamentally different characteristics depending on whether they are commonly learned by adult outsiders (exoteric languages) or only by children (esoteric) (Kay 1977, Chafe 1985, Thurston 1989, Trudgill 1989). Esoteric languages tolerate complexity, irregularity and semantic opacity, and natives may perceive them as a collection of large formulaic chunks (Laycock 1979, Thurston 1987). The third theme is how writing impacts on the complexity of language by supporting (a) autonomous (context-free) expression (Kay 1977), (b) the transition from clause-stringing to clause-embedding (Kalmár 1985), and (c) in consequence, the potential for Subjacency to apply for the first time (Newmeyer 2002). These issues can be accommodated within a single account, if we eschew the 'word' as the recombinable unit, in favour of the more inclusive 'lexical unit' (see below). We propose that humans naturally apply a pattern-recognition procedure to linguistic input, but are not naturally predisposed to select a consistent unit size (Peters 1983). They home in on phonological forms associated with effects that they need to achieve, e.g. object-naming, expressing a feeling, manipulating someone, carrying out a social function, conveying a nuance of meaning, narrating a traditional story. The units in their lexicon are, thus, variously morpheme-, word-, phrase-, clause-, and text-sized (Wray 2002a). A language that increases its autonomy (e.g. under pressure to be comprehensible to outsiders, and learnable by adult non-native speakers) will promote in its users and, indirectly, child learners, smaller units overall, altering the lexical balance and creating new opportunities for novel expression. But it is non-autonomous, isolated, esoteric languages that we may assume most closely resemble those of our early modern ancestors (Newmeyer 2002), and research here is consistent with the individual's lexicon typically containing a relatively small inventory of individual words for common objects and a lot of complete phrases with social functions (Laycock 1979:91), often impenetrable analytically to the point of being unlearnable other than by rote (Grace 1998:71; Laycock 1979, Thurston 1987, 1989). Three things follow: (1) The lexicons of the first language users may have contained fewer discrete words and morphemes, and required fewer grammatical rules to combine them, than most languages today. (2) Since forms acquired holistically need not be logical in construction (even etymologically) there need not have been an original inventory of morphemes and combinatory rules from which the first lexical units derived. Rather, the first fully human language(s) could have been fed by pre-existing sound sequences holistically associated with semantically complex messages (Wray 1998, 2000, 2002b; Kirby 2000). (3) Full compositionality is not a property that we have to account for at the dawn of language: it has developed in response to

particular social, political and cultural applications of language over time (Grace 2002a,b).

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No Mutation, No Correlation _ Language Evolution and Baldwinian Niche Construction

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Since Hinton & Nowlan published their seminal paper (Hinton & Nowlan 1987), the neglected evolutionary process of the Baldwin effect has been widely acknowledged. Especially in the field of language evolution, the Baldwin effect has been expected to salvage the long-lasting deadlocked situation of modern linguistics: i.e., it may shed light on the nature-nurture debate from an evolutionary perspective.

However, as intense research of this evolutionary theory go on, certain robust difficulties have become apparent. One example is genotype-phenotype correlation. By computer simulations, both Yamacuhi (2001) and Mayley (1996) show that for the Baldwin effect to work legitimately, correlation between genotypes and phenotypes is the most essential underpinning. This is due to the fact that this type of the Baldwin effect adopts as its core mechanism Waddington's "genetic assimilation" (Waddington 1975). In this mechanism, phenocopies (an environmentally induced phenotype that mimics the phenotype produced by a specific genotype; in this case, learnt phenotypes) have to be genetically closer to the innately disposed genotype. Indeed, the assumption is even tighter; among the learners, better learners are even closer to that of the innately adaptive individual. Through the selection for better learners, the innately adaptive genotype is also implicitly selected; the better learners natural selection chooses, the closer it gets to the innately disposed genotype. Unfortunately this is an overly na_ve assumption for the theory of language evolution. As a highly complex cognitive ability, the possibility that this type of genotype-phenotype correlation exists in the domain of linguistic ability is vanishingly small.

In this study, we investigate how Baldwinian Niche Construction can overcome this bewildering problem of the Baldwin effect. Baldwinian niche construction is a new type of mechanism of the Baldwin effect which has a rich explanatory power (Deacon 1997, Dor and Jablonka 2001, Odeling-Smee et al. 2003). By creating a new linguistic niche, learning discloses a previously hidden genetic variance on which the Baldwin "nativising" effect can take place. It requires no genetic modification in a given genepool. There is even no need that genes responsible for learning occupy the same loci as genes for the innate linguistic knowledge. These and other aspects of BNC are presented with some results from computer simulations.

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Can mimesis provide the "missing link" to language?

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Within the current context of many competing theories of the origin of language, an attractive idea is Donald's (1991, 1998, 2001) proposal of a mediating form of cognition, communication and culture between those of the common ape-human ancestor and modern humans based on *mimesis*. Donald defines mimesis most succinctly as "the ability to produce conscious, self-initiated, representational acts that are intentional but not linguistic" (Donald 1991: 168). Thus, mimesis constitutes a system of semiotic potential that is intermediate between animal communication and human language. Like language it is culturally learned, flexible and *potentially triadic* (see below), while lacking critical features such as full conventionality, arbitrariness and extensive systematicity. The mimetic hypothesis has also been backed up by evidence from archeology, neurobiology, cognitive psychology and developmental psychology, e.g. the homology between "mirror neuron" systems in monkeys and neural structures for the control of imitation, mentalizing and even language in human beings (Donald 1991; Zlatev 2002; Corballis 2002).

However, there are problems with Donald's proposal: On the one hand, his theory seems to underestimate the cognition of non-human primates with respect to planning, tool-making, gesture and the ability to understand intentions. On the other hand, it attributes so much representational complexity to mimesis (features such as reference, intentionality, autocuing, generativity…) that it in practice obviates the need for a second cognitive transition to language (Laakso 1993). Donald's formulation of mimesis can be said to give too little to apes and too much to *Homo erectus,* making it difficult to envision how this gulf can be bridged by a single transition.

In this paper, we attempt to remedy these drawbacks by reviewing the relevant primate evidence in order to see if certain mimetic skills are not within the grasp of non-human apes. In particular, we interpret ape cognitive-communicative capacities in three domains closely related to mimesis: *imitation*, *intersubjectivity* ("theory of mind") and *gesture*. In all three cases apes exhibit simple forms of these capacities which do *not* involve the central feature of mimesis – understanding "representative activity" (Piaget 1951) – and therefore can be regarded as *pre-mimetic*. Furthermore we distinguish between a *dyadic* form of mimesis – in which attention is paid to the distinction between self and represented object/action, or between self and other, but not to all three – and a *triadic* form of mimesis in which the addressee is (minimally) intended to pay attention to the referent. The primate evidence for the first form is robust, for example the spontaneous gestural communication of zoo-living gorillas (Tanner and Byrne 1999). However, as regards the triadic form, the evidence is debatable. Some language trained apes display it, but this could plausibly be a consequence of grasping the triadic nature of language itself. Therefore, we also consider what forms of imitation, intersubjectivity and gesture seem to be dependent on language, and are thus by definition *post-mimetic*. Such forms can by definition not be regarded as precursors to language.

In analyzing the progression: pre-mimetic > dyadic mimetic > triadic mimetic > post-mimetic, our study suggests possible evolutionary precursors to mimesis, such as neonatal mimicking. It also focuses attention on the type of mimesis that *could* provide the "missing link" to language – true *triadic* mimesis that is not dependent on language. However, the primate evidence is so far inconclusive on this point.

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Languages consist of collections of syntactic rules that specify how phonemes and words are put together into phrases and sentences. Although there are a number of known cases of syntactic rules in animal communication, there is no evidence to that these rules are important in determining the meaning an utterance, a crucial aspect of human syntax. Recent fieldwork has shown that the alarm call system of West African Campbell's monkeys (Cercopithecus campbelli) is controlled by a structural rule that affects the meaning of a call series. Here, I present data from a playback study designed to investigate a similar phenomenon in another closely related primate species, the sooty mangabeys (Cercopithecus atys). In this species adult males produce a conspicuous vocalization, the "whoop-gobble", in response to a number of general disturbances, such as a falling tree, the far-away alarm calls of a neighboring group, or a distant predator. Whoop-gobbles are often followed by long series of alarm calls of the kind also given to leopards, a dangerous monkey predator. Playback experiments have shown that nearby listeners pay little attention to mangabey alarm calls if they are preceded by whoop-gobbles. Alternatively, the exact same alarm calls elicit a strong leopard-type antipredator response in nearby listeners if the whoop-gobbles are artificially deleted from the call sequence, suggesting that the whoop-gobbles act as a semantic modifier for subsequent alarm calls. These experiments are taken to suggest that non-human primates possess some of the cognitive capacities necessary to process syntactically organized acoustic information, indicating that these abilities have evolved in the primate lineage long before the advent of modern humans.

Extending the Mirror System Hypothesis: Homologies, Comparative Neurobiology and Brain Imaging

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Arbib and Bota (2003) used two hypotheses on the evolution of brain mechanisms of language, that of Aboitiz & García (1997) and the Mirror System Hypothesis of Rizzolatti & Arbib (1998), to ground the search for homologies between different cortical areas in macaque and human. The data they used were focused primarily on information concerning the anatomy of brain regions and the connections between them. The present paper builds on this work by updating the analysis of homologies to more fully relate functional analysis of the monkey brain (neurophysiology of the behaving animal) to functional analysis of the human brain (starting with behaviors shared with monkeys and progressing to studies of imitation and language).

Aboitiz and García assume that the human brain evolved (in part) to support language. They offer an essentially retrospective theory. They look at features of the human brain, seek homologous areas of the macaque brain, note what has changed (some areas enlarge, some connections are strengthened) and then suggest how these changes could support a lexicon of spoken words and a syntax to bind them into sentences.

By contrast, Rizzolatti and Arbib offer more of a prospective theory. They start from an analysis of the monkey's capabilities, especially the fact that species-specific vocalizations have their cortical outpost in the anterior cingulate but that a different area, involved in hand movements, is homologous to Broca's area. The Arbib (2002) version assumes that the human brain evolved (in part) to support protosign and protospeech, with the richness of human languages being a "post-biological accumulation of inventions", and offers hypotheses on how intermediate stages from the mirror system for grasping led via imitation and protosign to protospeech. However, Rizzolatti and Arbib are relatively silent on the phonological loop and other working memory systems whose emphasis is an important feature of the Aboitiz and García.

On this basis, we will present a new conceptual model of neurolinguistic processing, incorporating lessons from the work of Aboitiz and García (and other authors) to address a number of shortcomings of the original Mirror System Hypothesis.

Note to reviewers: This talk will not be "yet another" exposition of the Mirror System Hypothesis but will rather review key data to ground the most comprehensive model that has been developed within this tradition to date, taking us "Beyond the Mirror".

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The evolutionary linguist's divining-rod: restrictive theory

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The main obstacle to a better understanding of the evolution of language is a paucity of factual evidence about that evolution. This view has been expressed, often with considerable force, by various scholars, including Noam Chomsky (1998, 2000), Jerry Fodor (1998), Steven Jay Gould (2002), Richard Lewontin (1990) and Massimo Piattelli-Palmarini (1990). The present paper argues that removing this obstacle requires the adoption of a particular kind of theories – theories which give highly restrictive characterizations of various sets of things that are believed to have been involved in language evolution. A characterization of a thing T is restrictive to the extent that it offers a basis on which T can be distinguished in a non-arbitrary way from all other things which, though they may be related to T, are in fact distinct from it. (Botha, 2003, 8).

The paper develops its argument with reference to one of the sets of things alluded to above: processes by which language are believed to have evolved. More specifically, it focuses on the process that has been referred to alternatively as "exaptation" (Calvin and Bickerton 2000), "preadaptation" (Lieberman, 1975, 1984, 1990), "reappropriation" (Wilkins and Wakefield, 1995), and "co-optation" (Carstairs-McCarthy, 1999). Accounts according to which this process has been central to some phase in language evolution, the paper argues, do not draw on restrictive theories of exaptation. Such theories would include conditions on the basis of which it is possible to deny or to assign in a nonarbitrary way the status of "exaptation" to entities whose evolution is at issue. As a consequence, the argument continues, it is not clear what kinds of evidence would be pertinent to justifying or criticizing claims to the effect that such entities are or are not exaptations. What is taken to be a paucity of factual evidence about the processes by which language has evolved, the paper concludes, is to a significant extent a consequence of a poverty of theories which characterize these processes in a restrictive way. Restrictive theories are needed for divining facts that may bear on the adequacy of accounts of language evolution.

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Language Needs A 2^{nd} Order Representations + A Rich Memetic Substrate

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Recent research has shown that human semantics can be replicated by surprisingly simple statistical algorithms for memorizing the context in which words occur (McDonald and Lowe, 1998; Landauer and Dumais, 1997). Assuming one accepts the point that semantics *is* the way that the word is uses (which cannot be argued in one page, but see Wittgenstein (1958) or Quine (1960), and which is the underlying assumption of memetics) then why wouldn't more species have supported the evolution of this useful system of rapidly evolving cultural intelligence?

Recent work in primatology tells us three relevant facts. First, we know that apes and even monkeys do have culture (de Waal and Johanowicz, 1993; Whiten et al., 1999). That is, behavior is reliably and consistently transmitted between individuals by non-genetic means. So we know that the question is not "why doesn't animal culture exist", but rather "why isn't it on the same scale as ours?"

Second, we know that primates have uniquely complicated social representations. For some time, this has been one of the basic hypotheses concerning why primates are so intelligent (Byrne and Whiten, 1988; Dunbar, 1995). But one particular aspect of social reasoning may be especially relevant to language – the ability to reason about agents relative to each other rather than simply maintaining a list of relationships between other and self. Harcourt (1992) presents evidence that all social species behave as if they keep record of relations between themselves and their group members (e.g. positive and negative interactions), but only primates behave as though they keep tabs on the relations between other agents. For example, apes will avoid fighting with close associates of dominant animals, and may try to befriend them (de Waal, 1996).

This sort of second-order representation and reasoning may be a necessary foundation for the compositional aspect of human languages. But if so, and we share it with other primates, why don't other primates display language and memetics? Perhaps there is another representation issue — this time the underlying representation which supports the disembodied communication of semantic content. If our memetic representation is a more fertile substrate for supporting unsupervised cultural evolution, then our culture would have a richer design space in which to evolve.

This leads to the third interesting discovery about primates: humans are the only species of primate capable of precise auditory replicative imitation (Fitch, 2000). My hypothesis is that the original basic unit of cultural transmission for humans was and is the auditory phrase. Auditory phrases are full of ordered information on a large number of axes: timing, duration, phonetics, and pitch.

There are a number of questions about this hypothesis, not least of which is whether other primates are capable of remembering precise timings for gestures: if not, they might have evolved a sign language as rich as our vocal one. However, if I am correct, and the trick is that the richness of the substrate representing the strictly semantic, ungrounded cultural transmission is the key, then we now have an explanation for why other primates don't share our level of culture.

	2^{nd}-ord. soc. rep.	no 2^{nd}-ord reps
vocal imit.	people	birds
no voc. imit.	other primates	most animals

Figure 1: Human-like cultural evolution might require both a rich memetic substrate as provided by vocal imitation, and the capacity for second order social representations.

Birds do have this same substrate (in fact, perhaps a richer one) but do not share the cognitive capacities of primates, possibly including the critical 2^{nd}-order representations. Thus the only other animals which might then hold a culture approximating our own are the cetaceans, the whales and dolphins. I will resist speculating about these.

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The sensorimotor origins of linguistic categories: Experiments with grounded neural network models

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The scientific investigation of the origins of language has significantly benefited from the use of computer simulation approaches (Cangelosi & Parisi, 2002; Kirby 2002). Computer models based on evolutionary neural networks and artificial life can be used to simulate the emergence of grounded language in populations of sensorimotor agents. These models make it possible to investigate the fine interactions, during evolution, between language and other cognitive, behavioural and neural abilities. In grounded evolutionary models, the communicative behaviour of agents is directly grounded in their cognitive and sensorimotor abilities. The evolution of language depends on the concurrent (or preceding) emergence of an ability to interact with the environment and to build a categorical representation of it. All behaviours are controlled by the same neural network or by a set of interconnected, modular networks. The analyses of the agents' neural networks allow us to highlight the neural mechanisms responsible for the integration of communicative, cognitive and motor abilities and the evolution of language.

In this paper new data on the relationship between the evolution of basic word categories and that of the sensorimotor abilities upon which they are built will be presented. The analyses of the neural networks were performed through using the Synthetic Brain Imaging method (SBI: Arbib et al. 2000; Cangelosi & Parisi, in press). This technique supports qualitative comparisons between empirical neuroimaging data on the neural processing of language (Pulvermuller, 2003; Cappa & Perani, 2003) and the control of linguistic behaviour in the neural networks of simulated agents. In our computational model, we evolve populations of agents that use two categories of communication signals: names of objects and names of actions. These respectively share some of the properties of the categories of nouns and verbs, albeit in a very simplified fashion. These signals can actually be considered proto-linguistic categories, in an evolutionary sense.

SBI analyses show that the neural representations of behavioural categories and that of word classes are sensitive to the level of integration of linguistic information and sensorimotor knowledge. The neural networks show a functional modular organisation that closely reflects that observed in humans through brain imaging studies (Cappa & Perani, 2003). The names of actions (nouns) are more active in the parts of the network that process sensory and visual information only (corresponding to the left dorsolateral areas in the human cortex). Words related to the names of actions produce more activity in the parts of the network where sensorimotor information is integrated (corresponding to the left prefrontal motor areas where verbs produce more activity). Overall, the model shows that the evolution of early proto-linguistic categories is dependent on the sensorimotor organisation of the agents' behavioural and cognitive abilities. The implications of this model and data for assessing the role of sensorimotor knowledge in the evolution of language and syntax will be discussed. In particular, this model supports hypotheses on the

re-organisation of the brain for the origins of symbolic abilities (Deacon, 1997) and the sharing of neural structures for linguistic and motor tasks (Greenfield, 1991; Reilly, in press).

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Is coevolution of language and language genes possible?

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Languages change fast; genes changes slowly. This presents a puzzle for any theory of language origins which assumes that (1) human language capacities are underpinned by genes for language specific constraints; (2) that these genes arose by adaptation to the linguistic environment. The puzzle is that the linguistic environment would seem to be too unstable to provide a consistent selection pressure on successive generations of learners. Moreover, because humans are geographically distributed, and linguistic change leads to divergence across linguistically unconnected or loosely connected populations, different populations of humans would appear to be under very different selectional pressure---i.e., pressure to be adapted to learn to cope with their own linguistic environment. Yet, it is typically assumed that language-specific genes do not differ across populations, but are instead universal---indeed, one motivation for proposing language genes is that they provide an explanation for universal properties of the world's languages. These difficulties appear to undermine the idea the adaptationist picture, according to which languages and language genes co-evolved. Instead, they suggest that language change is too variable to provide an environment for stable selectional pressures across over genes. This paper explores these arguments with a series of computer simulations of co-evolving populations: one population that mutates rapidly (analogous to language); and one population that mutates slowly (analogous to genes). The fitness function of elements in each population is determined by the "alignment" with the members of the other population (i.e., a language is 'fit' if it is easily learned; a learner is fit if it learns languages easily). We also present some results from simulations with spatial structure to their populations, attempting to model the geographically distributed character of human populations. From our theoretical arguments, and the simulations we present, we draw conclusions for the origin of language, arguing that the fit between language and language learners primarily arises from the rapid evolution of language to fit learners, rather than the other way around. These arguments present challenge for the adaptationist picture of the development of putative language genes with which we began. Indeed, we suggest, unless some plausible alternative to the adaptationist story can be developed, the very idea of genetically encoded language universals becomes problematic, purely on evolutionary grounds.

The Necessity of Innate Constraints on Cultural Transmission in Theories of Language Evolution

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Over the past few years the notion of cultural transmission has emerged as a key element of many theories of language evolution (e.g., Arbib, 2003; Davidson, 2003; Deacon, 1997; Donald, 1998; Givon, 1998; Tomasello, 2003). Although the exact scenarios differ from each other, the main emphasis is on explaining grammatical structure not as a product of biological evolution, but as emerging through cultural transmission of language across many generations of learners. Many proponents of this perspective on language evolution eschew the idea of Universal Grammar - a large endowment of innate linguistic knowledge (Chomsky, 1965) - as the endpoint of evolution. Nonetheless, in this talk I will argue that innate constraints on language are still necessary - even if one views language as primarily having evolved through processes of cultural transmission.

Without constraints on cultural transmission we would expect to find few commonalities among languages. Yet, the languages of the world – despite their many differences – also share many systematic similarities in their structure and usage, sometimes referred to as linguistic universals. Although the space of logically possible ways in which languages could be structured and used is vast, the world's languages only occupy a small fraction of this space. If the processes of language emergence are focused within the cultural domain then linguistic universals should be unlikely because it is possible to imagine a multitude of culturally useful, and equally adaptive, constraints on linguistic form. That is, cultural transmission on its own cannot explain the existence of universal linguistic patterns; it cannot tell us why language is structured the way it is, nor why language is so readily learnt.

I will argue that to answer these questions we need to include innate constraints on learning in theorizing about cultural transmission, but that these constraints need *not* be linguistic in nature. I will suggest that innate *cognitive* constraints on learning and processing, existing prior to the emergence of language, provided a niche within which cultural transmission could take place. Constraints on these learning mechanisms became "fossilized" in the structure of language because linguistic forms that fit these constraints were more readily learned, and hence propagated more effectively from speaker to speaker (Christiansen 1994; Christiansen, Dale, Ellefson & Conway, 2002). From this perspective, language has been shaped by cultural transmission over many generations to be as learnable as possible by the learning mechanisms of human children. I will point to a series of studies combining artificial neural network simulations and human artificial language learning to illustrate how constraints on sequential learning may be enlisted to explain specific universal properties of language.

I conclude that in order to explain why language looks the way it does today innate constraints must be taken into account when proposing cultural transmission as the primary component of language evolution but that, importantly, these constraints may be entirely cognitive in nature.

The evolution of language and elaborateness of grammar: the case of relative clauses in creole languages

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Recent research indicates that contrary to traditional assumptions (Trudgill 1983, Gumperz and Wilson 1971), language contact brings about diversification and complexification of grammar (Heath 1978, Aikhenvald 2002). This may involve more complexity with respect to contents, e.g. additional categories, additional variants of the same grammatical category, redefining of the same grammatical category. It may also involve complexity with respect to form (see also Kuteva, forthcoming), which we will refer to as elaborateness of marking, and which is at the centre of our interest in this study.

Given that language contact leads to increase in elaborateness of marking of grammatical categories, one would expect that the extreme cases of language contact situation, namely pidgins and creoles, would also involve elaborateness of marking.

With respect to pidgins, numerous studies have shown that this expectation is not borne out. One reason for this may very well be the lack of bilingualism in pidgin-related situations. The much more interesting question involves the other extreme case of language contact, creoles. The question here is: what degree of elaborateness of marking do grammatical categories exhibit in creole languages? This is the issue we address in the present paper.

In order to answer the above question, we will work with 3 language samples: (i) a genetically and geographically balanced sample of the languages of the world, (ii) a convenience sample of non-creole dialects/languages highly influenced by language contact, (iii) a convenience sample of creole languages. We examine the languages in the above samples for the way they mark relative clauses. Our preliminary results indicate the following degree of elaborateness of marking for the relative clause construction:

-genetically and geographically balanced sample of the languages of the world - in most cases, 1 marker

-convenience sample of non-creole dialects/languages highly influenced by language contact - in most cases, more than one marker

-convenience sample of creole languages - in all cases, 1 marker.

In other words, we show that the growth of phonological material for the marking of the relative construction in creole languages is no less and no more that one marker for one meaning.

We put forward a functional explanation for this fact. On the assumption that:

-what is functional involves a simple, iconic 1-to-1 form: meaning pairing; and

-both non-creole and creole languages start as

simple and highly functional systems (cf. also Comrie's 1992: 205 assumption that certain complexities of all or many presently attested languages were not present in early human language), we propose that creoles show the simplest and most functional structure of relative clause because their grammars are recent creations, which haven't had enough time to produce, "junk" or elaborateness.

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A unified computer model for internal and external constraints in language evolution

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During the last decade, an increasing number of computational approaches have been developed to study human language, which have employed notions such as dynamic complex systems or self-organization. The emergence of linguistic structures has especially received a great deal of attention; whether they focus on the lexicon (Steels 1996), phonetic inventories (de Boer 1999) or sets of syntactic rules (Batali 1997, Kirby 2002, Steels 2000), all studies share the goal of explaining how a coherent global system can emerge from simple local interactions. In parallel, a few computer studies have addressed the role of social parameters in language evolution, such as Nettle's study on social factors (1999), application of Steels' naming games to language contact (Steels 1997, Marsico & al 2000), or Niyogi & Berwick'(1997)s work on the competition of linguistic variants across generations. Such topics can benefit from the advantages of computer models and remain puzzling to most linguists: does a larger population evolve faster or slower? What parameters affect linguistic diversity? Is it possible to refine the glottochronology with additional social settings?

Because of a legitimate difference of focus, models of the emergence of language are usually limited when it comes to study social factors, as models on the evolution of languages often reduce language to an extremely simplified system. While these limitations are helpful to delimitate the role of each parameter, additional phenomena might emerge from the interactions of external (social) and internal (cognitive, production/perception) constraints.

To better investigate such interactions, we propose a model which offers a unified mathematical framework for both types of constraints weighting on a set of linguistic systems, also called agents, which can correspond to either idiolects or communal languages. To this end, we rely on the two key notions of fitness landscape and social network. Internal constraints are defined by a fitness landscape on which linguistic systems draw evolutionary trajectories. All possible states are predefined and no emergence occurs, but the shape of the landscape can be computed from a large variety of situations. Furthermore, a simple model of social network (Milroy 1993) leads to additional attractions or repulsions between agents, following intuitive statements such as Bloomsfield's proposal about the convergence of idiolects of closely and friendly related individuals (Labov 2002). Such a general social model allows investigating a large number of situations, from uniform populations of various sizes, to complex communities with more or less connected sub-networks.

For each agent, the direction of change is determined by the constraints derived from the local slope of the fitness landscape and his social environment. Random draws following probabilistic Gaussian distributions modelling the former constraints lead to the probabilistic evolution of linguistic systems. The global diversity of the population of agents and the mean rate of change can be measured from the trajectories of the systems in the landscape.

We present the conclusions of experiments which first consider the two

types of constraints independently, and then combine them to evaluate their respective influence. Among others, Nettle's results are reproduced, and the two types of constraints appear to be operationally independent. We also try to link various topologies of the social network with hypotheses about the prehistory of languages and its characteristic (diversity, rate of evolution). Further enhancements are finally reported, such as the on-going extraction of a fitness landscape from the UPSID database of phonological inventories in world's languages (Maddieson 1984).

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Title: Wild chimpanzees produce community-specific calls: a case for vocal learning?

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Vocal learning, where animals can modify the structure of their vocalizations as a result of experience, has been found in a range of birds and mammals. Although vocal learning is a fundamental aspect of developing spoken language, there is as yet little evidence that vocal learning occurs in primates (Hauser et al, 2002). Here we examine whether vocal learning may occur in chimpanzees.

We analysed whether wild male chimpanzees, Pan troglodytes verus, of four communities living in a similar habitat in the Taï Forest, Côte d'Ivoire, developed community specific pant hoots. If so, we expected males of three contiguous communities to have distinct pant hoots, while pant hoots of males from a fourth, distant community, located 70km away, should only differ from those of the contiguous communities by chance.

Our analysis confirmed these expectations. In addition, the acoustic distances between the pant hoots of pairs of individuals did not correlate with the genetic relatedness of those pairs, where genetic relatedness was determined using nuclear DNA analysis. Thus, neither habitat nor genetic differences accounted for the observation that there were acoustic differences in the pant hoot structure of males living in neighbouring communities, but not in those of males from a distant community. This suggests that chimpanzees may actively modify pant hoots to be different from their neighbours, providing support for the vocal learning hypothesis. The implications of these results in terms of the evolution of spoken language will be discussed.

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Who Forgot Paul Broca?

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Lateralization of language in man was first clearly recognised by the French neurologist, Paul Broca in 1861. In 1877 he formulated the hypothesis that lateralization of function was what distinguished man from other animals and gave us the capacity for language. Broca's hypothesis has been pursued particularly by Annett (2002) who has consistently defended the thesis that cerebral asymmetry is *sapiens*-specific, can be accounted for by a single gene, and that this gene is a major determinant of human cognitive ability and the capacity for language. Her conclusion that population-based directional asymmetry is specific to *Homo sapiens* was substantially reinforced by the studies of Marchant and McGrew of chimpanzees in the Gombe National Park, and by the subsequent careful cross-species comparisons in a series of primates by Holder who concluded that "No species level left- or right-handedness was found for any of the five species (common chimpanzee, red colobus, redtail money, grey-checked mangabey, and mountain gorilla) studied". In reviewing the primate literature, McGrew and Marchant concluded that "non-human primate hand function has not been shown to be lateralized at the species level – it is not the norm for any species, task or setting, and so offers no easy model for the evolution of human handedness". These conclusions are reinforced by the anatomical data of Buxhoeveden et al (2001) who looked at the minicolumn structure in the planum temporale and found that in the widths and separations, for example, there were asymmetries present in the human cortex that were absent in the chimpanzee and rhesus monkey. These studies thus substantiate the conjecture of Paul Broca and provide a possible mechanism for the speciation of *Homo sapiens* and saltational basis for the origins of language.

Yet papers have been published in Science and Nature with claims to have identified a primate precursor of language. In one study (Gannon et al (1998) lateralization of the planum temporale was reported in 17 out of 18 chimpanzees by a method (inserting cardboard triangles into the lateral sulcus) that clearly was not blind and is unlikely to have detected the asymmetry rediscovered by Geschwind and Levitsky in 1968. Yet chimpanzees were found to be more lateralized than Man! In the second study by Cantalupo and Hopkins asymmetries of Broca's area were detected in chimpanzees and gorillas that had eluded post-mortem studies in man and systematic MRI studies of cerebral asymmetry in much larger samples of human subjects. That observer bias has entered the literature on primate handedness has recently been statistically documented by Palmer (2002). A more rigorous and critical approach to directional asymmetry than is manifest in much of the literature is needed. Here Broca's hypothesis that directional asymmetry is the defining feature of the human brain will be defended with the imp lication that a saltational account of the evolutionary origin of language is required.

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ProtocadherinX and ProtocadherinY as candidate genes for cerebral asymmetry and language: Positive selective pressures in Hominid Evolution.

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The Out of Africa hypothesis implies that a discontinuity in hominid evolution occurred between 150 and 100,000 years ago and that this was associated with the innovation of symbolic representation. The implication is that the transition was mediated by a genetic change, and that this genetic change accounts for the capacity for language uniformly present in modern human populations.

What was the nature of this change and with what brain structural and functional rearrangements was it associated? Broca first suggested that directional asymmetry is the characteristic that defines the human brain and the correlate of language. The possibility of locating a gene was opened up by i) observations on deviations in cerebral asymmetry and the development of language associated with aneuploidies (anomalies of number) of the X and Y chromosomes, and ii) the discovery that specific changes in the structure of these chromosomes have occurred in the course of hominid evolution.

Through a translocation approximately 3 million years ago (followed by an undated paracentric inversion) the brain-expressed genes *ProtocadherinY* and *X* (that code for cell surface adhesion molecules) are present on the human Y and X chromosomes respectively whereas there is a single gene (*ProtocadherinX*) on the X in other primates. Sequence comparisons with the chimpanzee, bonobo, gorilla, and orangutan reveal negative (stabilising) selection on *ProtocadherinX* genes during great ape evolution but evidence of positive selection (selection for change) in hominids on the *ProtocadherinX* ectodomain and *ProtocadherinY* cytoplasmic domain.

We interpret these changes as consistent with the original translocation being the event that defined the Australopithecus-hominid boundary. We suppose that the presence of the gene on the Y was selected by advantages to males, probably through mate selection by females. Subsequently there were phases of selection on the Y and X sequence that we envisage are related to intermediate hominid species (Homo ergaster, erectus, heidelbergensis) and to the increases in encephalization quotient that occurred at one or more of the transitions between species. These changes all preceded the advent of modern human populations to which we speculate the paracentric inversion on the Y was critical.

There have been 21 significant (amino-acid altering) changes in the sequence of ProtocadherinX and ProtocadherinY (compared to two in FOXP2) in the course of hominid evolution. This pair of genes is the only gene sequence so far to be shown to be subject to positive selection selective to the hominid relative to the great ape lineage.
We argue that these chromosomal changes and the selective pressures on this pair of genes are relevant to the evolution of the sexual dimorphism of cerebral asymmetry, Broca's putative correlate of language

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Co-evolution of language acquisition and infant-directed speech

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This abstract presents an investigation of the role of infant-directed speech in the evolution and acquisition of complex language. It is proposed that infant-directed speech (the adaptation of a caretaker's utterances to the language skills of an infant) helps to stabilize more complex sound systems in a population. This enables more complex language to persist in a population and thus creates evolutionary pressure for better language acquisition skills. These ideas are investigated with a computer model and observations of real infant-directed speech.

The most frequent speech used by adults is rapid, casual speech. The utterances, and especially the vowels in this speech register tend to be strongly reduced. If infants would therefore be purely statistical learners, they would tend to learn reduced versions of the sound system of a language and especially of its vowel system. As this process is repeated over the generations, sound systems would rapidly collapse. This is not observed in practice, however. Sound systems, although changing over time, do not collapse. It must therefore be concluded that infants are not purely statistical learners.

Learning systems can deviate from purely statistical learning in two ways. Either the learned categories are manipulated to compensate for reduction, or learners make a selection of the input data and base their learning on the selected examples. The first hypothesis (the compensation case) can be defended by the fact that children probably have to perform a number of compensations when learning speech anyway. The adult vocal tract is different from the infant vocal tract and in order to learn the sounds of a language, a child has to compensate for this difference. An added compensation for reduced speech is then not unlikely. The second hypothesis (the infant-directed speech case) can be defended by the existence of infant-directed speech. Such speech appears cross-culturally and has properties that make it easier to learn (slower tempo, more exaggerated intonation and articulation, face-to-face interaction etc.) If infants would base their learning on infant-directed speech preferably, reduction would not be expected.

Transfer of vowel systems was implemented in an agent-based computer simulation. A population of agents consists of adults and infants. Adults have a fixed vowel system, and produce noisy, reduced utterances. Infants learn a vowel system from adult utterances. After a number of interactions, adult agents are removed from the population, infants fix their vowel systems and are converted into adults, and new, empty infant agents are inserted in the population. In the compensation case infants listen to reduced adult utterances, and compensate for reduction by expanding the vowel systems they learn. In the infant-directed speech case, adult agents produce less reduced utterances.

It is found that for five-vowel systems, both mechanisms transfer vowel systems perfectly. However, for larger (seven) vowel systems neither of them works well. In combination, however, they do preserve vowel systems in the population. As compensation can be argued to exist on independent grounds, the conclusion is that infant-directed speech is needed as an extra mechanism to preserve complex vowel systems. This

conclusion is supported by observations of real infant-directed speech. It is found that in languages with more vowels, infant-directed speech is more pronounced than in languages with fewer vowels.

The implication for language evolution is that relatively simple behavior by adults can facilitate the task of learning language by infants. This makes it possible for more complex language to persist in a population. If more complex language is stable in cultural transfer, this makes it advantageous for agents to evolve adaptations for such complexity. Thus adult adaptation to infant learning can bootstrap the increasing complexity of language.

>From Holistic to Combinatorial Signals

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The signals that all human languages use are combinatorial. Languages use a limited number of basic signals (depending on the theory these can be phonemes or syllables) that can be combined into an enormous number of possible complex signals. This is in contrast with holistic signaling systems, such as common in animal communication, where the signals cannot be analyzed as consisting of smaller units.

If holistically coded systems can contain a large number of signals, and if a holistic system was the precursor of the combinatorial system of human speech (which is likely given that primate call systems are all holistic) the question arises of how an originally holistic call system can evolve into a combinatorial system. Existing explanations for this transitions -- based on the intuition that, in principle, combinatorics provides an efficient way to produce a large number of signals -- are not entirely satisfactory.

For instance, it has been argued that combinatorial (phonemic) coding results in more reliable communication than holistic coding. However, such explanations for the emergence of phonemic coding do not take into account that holistic signals can have a long duration in time, and that a purely holistic system can thus contain many individual signals. Moreover, even if the possible fitness of a combinatorial system is higher than that of a holistic system, that is in itself not enough as an evolutionary explanation. Crucially, there must be a path of ever increasing fitness from a holistic system towards a combinatorial system. This is a serious constraint that can not be ignored, and -- as combinatorial systems are qualitatively different from holistic systems -- it is not trivial to imagine a system that falls in between.

The hypothesis investigated here is that when one optimizes a holistic system of signals for distinctiveness under noise, the resulting system can be analyzed as a combinatorial system. We used a computer simulation, in which a repertoire of sounds of a fixed duration is modelled. Sounds are (almost) continuous trajectories in an abstract acoustic space. We maximize the total acoustic distance between the trajectories in order to make them as distinctive as possible. After optimization, the resulting systems of trajectories appear to be coded combinatorially, i.e. a small set of points of the space is re-used as start- and endpoints of all trajectories. Crucially, the phonemic coding we observe in these simulation is superficial, and can not be used productively by the system, i.e. the system cannot create novel combination of existing building blocks.

The results do, however, suggest a novel evolutionary pathway from a holistic system to a combinatorial system. We assume an ancestral population with a small number of signals, that are randomly arranged in the available signal space and that cannot be analyzed as consisting of a smaller number of building blocks. When the number of signals increases, and they are optimized for distinctiveness under noise, the way they are arranged in the signal space becomes less random: the signals can now in principle be analyzed as being built-up from a number of smaller building blocks. For an outside observer, the signals are combinatorial. However, the "agents" that use these signals do not yet make use of their combinatorial nature. They just learn and

reproduce these signals as if they were completely holistic.

The final step, which goes beyond the results of our simulation, would be for the agents to start making use of the combinatorics of the signals. Instead of learning the signals as holistic units, they learn the basic building blocks and the combinations. This requires less learning effort, and would allow these agents to produce new signals more easily. Hence, agents that make use of the combinatorial nature of the signals would have an evolutionary advantage. However, a small set of these signals would also be perfectly usable by agents that can only use holistic signals, thus ensuring evolutionary continuity and continuously increasing fitness.

The Interplay of Language and Human Evolutionary Histories

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The evolution of the capacity for language, including linguistic universals, cannot be meaningfully separated from the history of languages, but also the reverse holds true. The evolution of language and languages have taken place in the broader context of human evolution, the feedback cycle being mediated, on one side, by cultural selection on learnability and usability of languages, conducing to glossogenesis, and on the other side, by a form of linguistic Baldwin effect.

This realization implies that different models of human evolution should be correlated with different models of language (and languages) evolutionary history. At the two extremes there are the Recent-Out-of-Africa and Multiregionalism, but there is also a class of intermediate models. The nowadays almost universally accepted Recent-Out-of-Africa should imply a recent common ancestor of (almost) all modern languages as well as a small individual and regional variation in linguistic capacity. Multiregionalism should imply a deeper common ancestor of modern languages as well as a more pronounced individual and regional variation in linguistic capacity.

Empirically testing this hypothesis is feasible, even if not a simple task, using a series of tests like: adopted children in cultures speaking languages of different linguistic family than their own, comparative performance on equivalent linguistic tasks of adults speaking different languages, etc.

The present study employs a computer modeling approach. It involves regional populations of linguistic agents, able to split, migrate, replace or interbreed with pre-existing populations as well as linguistically interacting with them. The language is simulated using a series of linguistic properties which are genetically encoded but flexible enough as to be modified through learning during the critical period (there are learning costs associated in order for the Baldwin effect to take place). The preliminary study suggests that in this case the presence of the Baldwin effect can have detectable consequences on the linguistic map and it thus indicates that a more complex study targeted at testing the relationship between human evolutionary models and language evolution is relevant and worth pursuing.

ANOMALOUS LANGUAGE PERCEPTION AND SPEECH OF SCHIZOPHRENIA

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Schizophrenia is a uniquely human brain disorder that involves misperceptions of speech and disturbance in its complex structure. The symptoms characteristic of this disorder are commonly described as auditory hallucinations, delusions, formal thought disorder, and/or reduced thought, speech, emotions and withdrawal, but can all have their basis in language disturbance [1]. Numerous studies have found patients with schizophrenia to be deficient in various measures of sentence complexity and semantic associatio ns [2]. In addition, several functional imaging studies using language paradigms as stimuli have found that patients with schizophrenia have less lateralized focused activity [e.g. 3]. Structural imaging studies taken together show that brain cortical regions specifically known to be responsible for components of language are reduced in size and reduced in the normal left greater than right asymmetries (i.e. prefrontal cortex, superior temporal gyrus, planum temorale [4,5]). It is proposed that the underlying cerebral basis for schizophrenia comes from anomalies in the neuronal connections between these crucial structures for normal human language functioning and that these anomalies are genetically controlled and develop slowly over time [6]. From late adolescence to early adulthood as these connections reach maturity and a peak level of myelination, a threshold is reached whereby normal language pathways are disrupted. Is then the origin of schizophrenia associated with the extreme end of language evolution gone wrong (similar to hypothesis expressed previously by Crow [7]? If so, can new treatments be developed to reverse these brain anomalies or to prevent their formation? That is the challenge we face.

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From Holophrases to Abstract Grammatical Constructions in Development and Evolution

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Previous research (Dominey 2000a,b; 2002) presented a sentence-to-meaning mapping model which learned abstract grammatical constructions that could systematically generalize to novel sentences. The model failed however to account for the transition from agrammatical holophrases to these abstract grammatical constructions. The current research addresses this transition issue in the context of development (Tomasello 2003), and evolution (Wray 2000) within the framework of a construction-based model of language acquisition.

Construction Model: The model is based on the principles that (1) grammatical constructions are mappings between sentence structure and semantic structure, and (2) that grammatical constructions can be identified, for storage and retrieval, by the pattern of closed and open class words unique to each construction type.

Abstract Constructions: In the abstract construction framework, constructions are identified by the *identity* and relative position of closed class elements, and by the *lexical category* and relative position of open class elements. Thus, for example, two distinct transitive sentences made up of different open class elements will correspond to the same grammatical construction and the same form to meaning mapping. This allows the model to generalize in a systematic manner to new sentences based on learned grammatical construction types (Dominey 2000a,b; 2002).

Holistic Constructions: However, developmental (Tomasello 2003) and evolutionary research (Wray 2000) indicate that the use of abstract constructions is preceded by a stage in which utterances are treated as distinct holophrases. In this phase, each holophrase utterance should correspond to a distinct construction. This reflects the case where the functional category of open class elements (e.g. names) that can be instantiated as variables or slots within abstract constructions has not yet been formed. Thus in the model, constructions are identified by the identity and position of all open and closed class elements (i.e. the entire utterance), so that each sentence is represented as a holistic and distinct construction, with the resulting limitations on expressiveness and generalization.

Transition from Holophrase to Abstract Construction: When the lexical category of concrete objects or nouns begins to emerge, these idiom-like holophrases begin to be replaced by partially generalizable "pivot" schemas like "Gimme ____" where the "___" corresponds to an object name variable (Tomasello 2003). In the model constructions, these nouns become represented by their lexical category, rather than by their identity. Verbs remain undifferentiated and are thus bound to distinct constructions. This leads to an item-based "verb island" phase (Tomasello 2003). The subsequent generalization on verbs allows for the full abstract construction capability. Simulations demonstrate that the progressive emergence of lexical categories will be correlated with the emergence of progressively more abstract constructions that generalize over those categories. This is consistent with the evolutionary analysis proposed by Wray (2000), in which during an extended period of holistic language use, cognitive abilities develop so that the emergence of naming allows the development of argument structure and the progressive segmentation of holistic utterances.

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Manipulations of fundamental frequency and formant dispersion influence attractiveness of male voices: Female preferences for testosterone dependent traits in male voices.

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We consider the possibility that the physical structures of the vocal apparatus allowing human speech may have evolved via the processes of sexual selection. Recent research has shown that female preferences for males with low fundamental frequencies may be potentially adaptive. Here we manipulated 2 sexually dimorphic properties of real male voices (fundamental frequency and formant dispersion) separately and in conjunction to isolate the effects of source (fundamental frequency) and filter (formant dispersion) characteristics on vocal attractiveness, perceived vocal health, masculinity, size, and age. Females rated male voices with lowered fundamental frequencies as more attractive, healthier, more masculine, larger, and older than rated male voices with raised fundamental frequencies. Male voices with decreased formant dispersion were rated as more masculine, larger and older, but not more attractive or healthier than male voices with increased formant dispersion. Only larger females preferred the male voices with decreased formant dispersion, suggesting assortative preferences for male size as indicated by filter characteristics of the vocal tract. A combined manipulation of raised fundamental frequencies and increased formant dispersion decreased female ratings of attractiveness, health, masculinity, size, and age. In normal males, pubertal testosterone levels determine fundamental frequency. Immunocompetence theory states that only the fittest males should be able to afford the immunosuppressive effects of testosterone. Therefore, males with relatively high testosterone should be most attractive because they should be healthy, dominant individuals. Here, we show support for this theory because simulating the effect that testosterone has on the male voice increased perceptions of attractiveness and health, whilst simulating an increase in vocal-tract length had no overall affect on perceptions of attractiveness and health.

Co-evolution of Language and Cognition

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The first part of the paper (A) analyses the concept of *co-evolution* when applied to instances where language is one of the two partners (brain & language, language & cognition). At a level of subsystems, the dynamics of the co-evolution of language and cognition forces an intimate coordination and co-evolution of those perceptual- and motor-systems involved in language-perception and -production. This process seems to result, as discussed below in part (B), in language universals regarding the "size" and internal structure of clauses.

(A) "Co-evolution" means a mutually dependent evolution of at least two "partners", most usually of two different species such as symbiotic living animals. If language is viewed as one of the two partners, the situation is different in an essential respect: Now selective pressure does no longer come from the "environment" (incl. other species) in the usual sense but from the respective species' own product. A significant step forward in the evolution of language makes growing demands on relevant cognitive capabilities and has, moreover, positive "retroactive" effects upon the development of these capabilities. The mutual stimulation between cognitive development and the development of language might explain, at least in part, the "acceleration" of the evolution of homo [1].

(B) The mean length of the translations of 22 simple German sentences into 34 different languages was found to be located in the area of Miller's magical number 7, ranging from 5 syllables in Dutch to 10 syllables in Japanese. And the whole set of crosslinguistic correlations [2] found between the 4 parameters n of phonemes per syllable, n of syllables per word and per clause, and n of words per clause points, first of all, to time-related constraints (e.g.: the more syllables per clause, the fewer phonemes per syllable). But these time-related constraints do not overrule the magical number 7. We will present strong indications that this number even shows in "long-term memory" materials such as the languages' repertoire of cases and of gender and person distinctions. This is not too surprising if we remember Mandler's (1967) experimental findings on "subject-imposed categorisation" and the mechanisms proposed in Anderson's ACT-theory.

We may summarize: The rhythmic segmentation of our natural languages corresponds with many spans or limits known from biology – intonation units can be viewed as a special case of action units [1] – and from psychology. A span of about 2 sec (cf Baddeley's articulatory loop model) and of about 7 syllables seems to be the appropriate size of "packages" that can be kept within the focal attention and that can be articulated within one intonation unit. We think that these correspondences can best be explained by an intimate co-evolution of all systems involved in language use, and one may speculate if our literate societies' inclination to construct longer sentences will stimulate this co-evolution in the sense of a further expansion of the "spans" discussed.

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Jumping from simple communication to language.

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ABSTRACT

Syntax and symbolic reference are usually dissociated in the study of the origins of language although both seem to be essential traits (Knight et al., 2000). Instead of debating which one is the most important, we propose an integrative path.

We define a simple form of syntax and a high order form of reference based on connectedness in a network of signal-object associations (Ferrer i Cancho, 2003a). Our higher form of reference is consistent with Terrence Deacon understanding of symbolic reference (Deacon, 1997; Deacon, 2003). Existent criticisms to that understanding (Hudson, 1997; Hurford, 1999; Poeppel, 1997) are reviewed and discussed. Following the approach by Ferrer i Cancho (2003b), we show how a simple communication system (namely signal-object associations) can jump to such a primitive form of syntax and symbolic reference in a way that different human language universals such as heavy-tailed signal frequency distributions (e.g. Zipf's law) and various statistical features of syntactic dependency networks (Ferrer i Cancho et al., 2003c; Ferrer i Cancho et al., 2003d) are reproduced. While there are many possible ways of explaining the origins of a primitive form of syntax (Nowak and Komarova, 2001; Kirby; 2002), our approach is unique in the sense it makes successful predictions about the real features of language.

The model relies on taking into account the coding effort, that is the cost of finding the proper signal for a given object. Such a cost is usually neglected in computational and mathematical approaches to the origins of language (Kirby, 2002; Nowak and Komarova, 2001).

One of the hardest problem that Darwinian evolution models of syntax need to face is how variation for syntax is offered to selection when there is no syntax at all (Bickerton, 2000). Here we show that simple communication constraints in a noiseless channel can offer syntax for free, covering a gap in innatist approaches to the origins of syntax (Nowak and Komarova, 2001). We support that human language is a by-product of simple communication.

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What nonhuman primates can, and cannot, tell us about the evolution of speech

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This paper will provide an overview over some of the key issues that have been studied in the vocal communication in nonhuman primates with regard to the evolution of speech. I will use Hockett's design features of speech (Hockett 1960, _Scientific American_, 203, 88-96) as a starting point to compare the communicative abilities of nonhuman primates and humans. A number of studies have addressed the question of 'meaning' in primate communication and have specifically examined whether primate vocalizations refer to objects or events in their surroundings. Present findings suggest that listeners use calls as predictors of events in their surrounding, while there is less evidence that the callers intend to provide this information. This form of 'functionally referential' communication has now been described for a number of animal species, including birds, rodents, and carnivores. Although nonhuman primates may voluntarily control the _onset_ of vocalizations, they lack the neural projections from the primary motor cortex to the laryngeal motor neurons. Consequently, they have little control over the _structure_ of their calls. Unlike songbirds or some cetaceans, nonhuman primates appear unable to mimic novel sounds or incorporate new sounds into their repertoire. The apparent inability to modify call structure also poses a barrier for the arbitrary pairing of sound and meaning, one of the key features of human speech. Nonhuman primates also lack a combinatorial system to generate new meanings from reordering the units of their communication, despite the fact that a number of studies have shown that listeners' responses to calls may vary with regard to the combination of different call types. In sum, there is a wide gap between the verbal production of human speech and the vocalizations of nonhuman primates. The findings highlight the importance of evolutionary constraints that apparently operate on the vocal communication of primates, a great deal of which can be attributed to differences in the neural substrate underlying the production of sounds. However, current reports about the gestural communication in nonhuman primates do not support the view that it is the lack of motor control alone that prevents nonhuman primates from more elaborate communication. I will argue instead that limitations in social cognition also play an important role in constraining the evolution of speech.

Surveying hypotheses for the evolution of language

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Scientific consideration of the evolution of language has reached a stage where both the number of hypotheses and the mass of data available to test them demands a dispassionate survey of multiple available hypothesis. Speculative hypotheses about the evolution of any single component of the language faculty abound, but the task of constructing a coherent account of the evolution of the many elements underlying language in a broad sense is far from trivial. Plausible hypotheses must be consistent with both available comparative, fossil, linguistic and neural data, and accepted neo-Darwinian theory. Features of language to be accounted for include speech production, especially vocal imitation, meaning, and complex syntax. Evolutionary forces to be reckoned with include natural selection, sexual selection and kin selection on either the communicative or the cognitive benefits of language. Constraints to be satisfied include compatibility with modern evolutionary theory, known hominid phyogeny, existence of plausible precursor abilities in animals, and conservatism of the vertebrate brain (and genome).

A brief survey of single-cause hypotheses suggests that none are adequate to account for all features of language. Thus some variant on a two-stage hypothesis, incorporating selection on an intermediate "protolanguage", seems necessary. I consider four such hypotheses in more detail: Condillac's gestural origins hypothesis (Corballis, 2002), Bickerton's asyntactic protolanguage hypothesis (Bickerton, 1995), Merlin Donald's mimetic stage (Donald, 1993), and Darwin's prosodic protolanguage hypothesis (Darwin, 1871). The focus by many scholars on sexual selection for language evolution has drawn attention away from kin selection as a much more plausible alternative for the evolution of complex propositional meaning. Although at present none of these hypotheses is perfect or complete, I conclude that Darwin's hypothesis, with some updating (see Fitch (in press)), along with Donald's, provide the best fit to available data, and leave the fewest questions unanswered. More importantly I conclude that such multi-hypothesis comparisons will help bring structure and unity into the developing discipline of language evolution.

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TOWARD AN EXPERIMENTAL METHOD FOR STUDYING THE EMERGENCE OF HUMAN COMMUNICATION SYSTEMS

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In 1953, Wittgenstein proposed that we understand language under the guidance of two related metaphors: The metaphor of language as a game and the metaphor of words as tools (Wittgenstein, 1953). In the fifty years elapsed since Wittgenstein's proposal, the metaphors have turned into fully fledged theories (Clark, 1996; Millikan, 1984). One of the central tenets of these theories is that our understanding of natural languages should be grounded in the study of the procedures humans develop to coordinate their cooperative activities. A method that allows a systematic experimental investigation of the emergence and the development of human communication systems would provide an ideal opportunity to test these theories. However, to our knowledge, no such general method currently exists. Typically, investigators study the emergence of human communication systems either via natural experiments (e.g., Bickerton, 1981; Goldin Meadow & Feldman, 1977; Kegl, 1994) or via simulations with artificial agents (e.g., Hutchins & Hazlehurst, 1995; Parisi, 1997; Steels, 1998). The latter option has the desirable feature of allowing experimental control, the former that of preserving the richness of human behavior. This paper introduces a method that combines the two features.

In brief, the method focuses on how communication procedures emerge from the exchange of visual signals between adults. Two participants play a videogame with two interconnected computers located in different rooms. Players do not know each other's identity but share the virtual environment of a game that requires them to coordinate their moves. Success critically depends on establishing effective communication procedures. However, the experimental set-up does not support the use of conventional communication systems. Spoken language is not possible because there is no audio channel. Visual communication is possible, but occurs through a device whose parameterization effectively prevents the use of handwriting or print. More in detail, players communicate with each other by using a magnetic stylus on a small digitizing pad. The resultant tracings are relayed to both players' screens and quickly fade. Crucially, while the horizontal component of the player's movements directly controls the horizontal movements of the trace on the screen, the trace's vertical component is independent from the player's movements, moving with a constant downward drift. In such conditions, the use of letters or other common graphic symbols such as numbers is practically impossible. (The problem players face is similar to the problem one would encounter in making a polygraph write words or numbers.) Hence, success in the game depends on the pair's ability to generate a novel communication system that befits the available channel.

The paper presents a study conducted with twelve pairs of participants that is designed to assess the suitability of the method for research. In brief, the study demonstrates that the method is viable. Pairs developed novel communication systems in a reasonable time-frame, often adopting fairly sophisticated communication procedures. The results of the study will be discussed in some detail in the context of an assessment of the potential and the limitations of the proposed method.

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Pretend Play in Pan: How does symbolic knowledge affect representational play?

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Human language is part of a suite of representational capacities (Piaget, 1951). The evolutionary history of these capacities is therefore of great interest to an understanding of the phylogeny of human language and the human symbolic capacity more generally. One approach is to investigate representational capacities in our closest living relatives, the genus Pan. Commonalities between Homo sapiens and Pan in representational capacities indicate a possible evolutionary foundation present 5-7 million years ago (Byrne, 1995; Cantalupo & Hopkins, 2001; Gannon, Holloway, Broadfield, & Braun, 1998). One capacity of particular interest is pretend play (play behavior that has an imaginary component) because pretend play develops so early in human children, around the same time as early language, and proceeds through a sequence of regular stages or steps in its development (Mitchell, 2002; Piaget, 1951). These stages allow us to ask not only whether apes can imagine, but what stages are evident in their play and whether the ordering of stages - the ontogenetic sequence - follow that of humans.

Because most examples of pretend play in apes come from home-reared apes or apes socialized with humans (Byrne, 1995; Mitchell, 2002; Suddendorf & Whiten, 2001; Tomasello & Call, 1997), the influence of human enculturation on the development of pretend play is of particular interest. One possibility is that the enculturation by humans stimulates the biological capability for pretend play extant in apes. In that case, the human enculturation could be perceived of as scaffolding in the Vygotskian sense - stimulating the apes' abilities within their zone of proximal development (Vygotsky, 1978). Pretend play in humans has been shown to be the outcome of a scaffolding process (Bondioli, 2001; Farver, 1993; Zukow, 1986)

Here we present the results of a systematic, qualitative study on pretend play in the symbol-competent apes of the Language Research Center. These apes have been previously shown to understand English at the level of a 2 1/2 year-old child and utilize symbols printed on a plastic keyboard to communicate with researchers (Brakke & Savage-Rumbaugh, 1995, 1996; Savage-Rumbaugh, McDonald, Sevcik, Hopkins, & Rupert, 1986; Savage-Rumbaugh et al., 1993) Our data come from over 100 hours of videotape taken over the course of 10 years of study on three bonobos (Pan paniscus) and two chimpanzees (Pan troglodytes).

We utilize the levels of pretend play described by McCune and Agayoff (2002) and based on descriptions by Piaget (1951). Our results show that the language-competent apes demonstrate pretend play up to level 4 spontaneously, but all examples of level 5 (the highest level) pretend play are initiated or scaffolded by human researchers. In contrast, the non-language-competent apes show pretend play at much lower stages than the language-competent apes and are unaffected by the researchers scaffolding attempts. These results suggest that sharing in human symbolic culture plays an important role in apes reaching higher stages of pretend play. The symbol-competent apes, therefore, provide us with an important model to further study the relationship between language and pretend play.

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The Rhetoric of the Evolution of Language

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The "rhetoric of science" is a well-developed field of inquiry (Gross 1996), but it has failed to focus in detail on the rhetoric behind current evolution of language debates. To address this lack, my paper analyses the rhetorical arguments of two stories making the rounds in contemporary cognitive science. First, there is the origin of language story told by Fauconnier and Turner in chapter nine of their recent book, The Way We Think: Conceptual Blending and the Mind's Hidden Complexities (2002). Pinker, Bloom, Chomsky, Klein, Mithen, Deacon, Calvin, and Bickerton, among others, are all mentioned by Fauconnier and Turner (some are referred to favourably, most are not). In my analysis of this argument, my focus will be on what does or does not count as evidence for Fauconnier and Turner as they try to muster support for their hypothesis that the rise of our capacity for conceptual integration accounts for the origin of language. The second story I analyse is the one about language and the FOXP2 gene reviewed by Marcus and Fisher (2003) in Trends in Cognitive Sciences in June 2003. In my analysis of this argument, I focus on the analogical reasoning that underpins the view that language and genes are necessarily related. While Marcus and Fisher hold that FOXP2 cannot fairly be called the "gene for speech" or the "gene for language," this was not at all how the FOXP2 story was first reported to the public. The press coverage hailing "the discovery of the language gene" in 2001, after the article on FOXP2 by Lai et al. (2001) appeared in Nature on 4 October 2001, reveals both a belief in genetic determinism and the interdependence of science and rhetoric. My overall goal in the paper is to recognize that one of the things that may make the evolution of language a contentious research topic is the nature of the evidence called on to justify competing hypotheses. How the evidence is reasoned with is also a concern of mine. For those at this conference who are engaged directly with research into the evolution of language, it might be useful to recall that the science studies community in general, and the history of science community in particular, will no doubt analyse the evolution of language debate in depth in the future. This paper, therefore, simply offers an initial look at what that examination might entail.

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What can the study of handedness in nonhuman apes tell us about the evolution of language?

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There is considerable debate over the origin and evolution of human language. Over the years, several different evolutionary pathways have been proposed. One popular theory is that speech evolved from nonhuman primate vocalisation, such as alarm calls. Another possibility is that language evolved from a system of manual gestures, or language may have arisen as a supplement to social grooming. However, none of the proposed theories has provided us with a convincing answer that is agreed upon.

However, since the discovery of the so-called mirror neurons, there has been renewed interest in the connection between manipulation and gesturing and spoken language. These neurons become activated when a monkey or human is grasping or manipulating an object or observing someone else doing the same motion, that is, they respond to visual stimuli. While mirror neurons are present in both left and right ventral premotor cortex in monkeys, they are only present in the left hemisphere, part of Broca's area, in humans.

The perceived connection between manipulation and gesturing and spoken language, which has been reinforced by studies of mirror neurons, has resulted in handedness often being used as a means of investigating the evolution of language. Modern humans show species level right handedness (i.e. a left hemisphere dominance), and much work has been conducted on nonhuman primates to trace the evolution of right handedness.

One of us (RH) has conducted an extensive examination on limb preference in captive apes under different behavioural conditions. The results from this study did not reveal any significant species-level handedness.

If we believe that there is a connection between handedness and language capabilities then, from these results, the latter must have evolved since the split between chimpanzees and hominids. The alternative is that handedness has no relation to language capabilities and that the latter evolved earlier.

A Perspective on Language Evolution from Studies of Graphical Languages

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The possibility of successful human communication is often explained by appeal to internalised representations or codes that enable the processing and interpretation of natural languages. Evolutionary theory is often invoked to address difficulties in explaining how such codes could be internalised or naturalised. We argue that no viable evolutionary account has been offered that can explain the how such an internal representation could have evolved. Accounts that appeal to computational advantages face the problem that natural languages are poor media for computation and that it is the development of external representations such as drawings and scripts, not language, that is most tightly correlated with enhanced cognitive abilities. Accounts that appeal to communicative advantage often appeal to some form of group advantage for their evolutionary mechanisms and thus, inherit the problems with group selection. We argue that the premise that human communication depends on some form of 'shared' code is incorrect.

We propose instead that the concept of communicative success should be understood in terms of mutual-indiscriminability and that language evolution should be understood in terms of the mutual-modifiability of the artifacts and technologies that are used to support the language. These ideas are illustrated by experiments on the evolution of graphical languages.

Recent research has shown many relations between spoken dialogue and written dialogues employing only graphical (non-character based) elements[Healey et al., 2002b]. For example, participants in graphical exchanges match each other's style of drawing more often than would be predicted by chance ([Healey et al., 2002a]), this echoes the 'entrainment' phenomena that have been identified for verbal dialogue[Pickering and Garrod, 2003]. Similarly, it has been shown that under some circumstances, patterns of graphical turn-taking emerge that are similar to those found in conversation[Umata et al., 2003]. Given these parallels, we wish to suggest that a greater understanding of the evolution of language in general can be gained from the study of the evolution of language in these graphical dialogues.

In previous work, we have shown that when the level of communicative interaction between the participants varies, the form of the representation produced by the pair also varies [Healey et al., 2003]. These results suggest that three different processes contribute to changes in graphical form in these tasks: practise, reduction and mutual-modification. We propose that the last of these, mutual-modifiability is central to the evolution of new symbols and new representational systems. The reduction of recurring representations, by definition, ia a conservative process that can support refinement of representations but not changes in their interpretation. For concepts that need to be communicated often, the main problem is arriving at the most efficient label for that concept. However, the development and modification of new conventions requires processes that can sustain generalisations across multiple concepts. This entails being able to modify and adapt the semantics of the representational system. Mutual-modification, we propose, provides a basis for this by providing mechanisms through which individuals can co-ordinate their interpretations of their evolving graphical language.

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Speech skull: From the bony structure of the head to soft tissues of the vocal tract

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Within the frame of language origin debate*, this project aims at defining possible speech prerequisites in the geometry, the musculature, and the control of the vocal tract. In order to answer these questions one should be able (i) to describe the structural relationships between landmarks of the skull and the jaw (the supporting structures of vocal tract); (ii) to reconstruct the geometrical limits of the vocal tract from these bony structures; (iii) to adapt an anthropomorphic model of the vocal tract to a given skull; (iv) to generate the corresponding maximal vowel space. This work is the first step of a larger project aimed at reconstructing the vocal tract from a cranium, modern or fossilized, in particular Neandertal. We present results derived from xeroradiographic data of 45 subjects (males and females) uttering /i a/ vowels or in a resting position. We used 19 landmarks corresponding to skull, jaw, C2 to C5, hyoid bone and extremities of the vocal tract (lips, pharyngeal wall and glottis). The data were acquired with the help of Craniomat, a software specially developed in collaboration with radiologists, anthropologists and speech scientists. To predict soft tissues landmarks and avoid a simple fitting of the data observations, we use the jackknife test. We take away one skull from the learning set for the remaining skulls, we learn a linear relation to predict the soft tissue landmarks from bony landmarks, we calculate the error of prediction on this skull, then we repeat learning and prediction for all the skulls and evaluate the mean error. We present the best predictors and error estimation for training and prediction. For lip protrusion, hyoid height, and glottis height, errors of prediction are assessed in relation with the range of observed data. This first step permitted us to show that it is possible to predict the extremities of the vocal tract (lips, pharyngeal wall, glottis) given the bony structure. In order to corroborate and extend our method we present first results concerning the predictions to other skulls going back in time: Egyptian mummies (2,000 years B.P.), CroMagnon (20,000 years B.P.) and Neandertal (45,000 years B.P.).

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* This research is a part of Orofacial control in communication in human and non human primates, EUROCORES program, being part of The Origin of Man, Language and Languages (OMLL) project funded by European Community.

Social factors as a major influence on vocal communication: song learning in European starlings

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Amongst the several parallels found between human language and birdsong development (Marler 1967), the importance of learning from conspecifics has taken an increasing part in recent findings. In particular, the nature and intensity of social influences on vocal development remain an intriguing question. In the present study, we report observational data on vocal learning and sharing in social groups of European starlings as well as results of an experiment aiming at investigating the importance of social bonds versus auditory information on song acquisition.. In this study, hand raised starlings were kept in different social conditions (socially housed with peers and adults, pair-isolated, single isolated) all receiving the same auditory information with live interactions between adults.

Results of this experiment confirm:

1) that song acquisition is higher with live tutoring,
2) that in starlings song learning follows sexual lines: socially housed females learned little from the adult male model,
3) that social experience can override auditory information: pair raised animals did not learn from the adult models heard through the loudspeaker but developed as shared improvised repertoire whereas the socially raised animals learned more, as a result of their preferred social bonds, from each other than from the adult models.

The results will be discussed in terms of social preferences and attention. They raised interesting general questions about the role of social constraints on the evolution of vocal communication.

Sea-crossings capacities and opportunities during prehistory: Survey and comparison between Homo species

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First sea-crossings during prehistory can be considered as tangible clues of a sophisticated communicative system, along with other behaviours such as ritual burials or art production. This conclusion can be drawn either from the technological capacities required to build rafts (Davidson & Noble 1992) or the planification and motivation necessary to undertake dangerous sea-crossings over large sea gaps (Hombert & Coupé 2002). The best known and studied example of distant sea-crossings is the one involved in the colonization of Australia by Homo sapiens around 60,000 years ago.

If modern behaviours become numerous at the beginning of the Upper Palaeolithic and the so-called Cultural Explosion at around 50,000 BP, scholars argue about the existence of such behaviours in earlier Homo sapiens (d'Errico & al 2001), and even more in earlier representatives of the Homo gender. Relations between language and tools, early sepultures or clues of a symbolic thought can all be discussed and put into question because of possible misinterpretations of the data. In this context, the distant colonization of Australia around 60,000 years ago already antedates the former limit of 50,000 years, but identification of possible earlier sea-crossings is valuable to better assess the emergence of modern behaviours, and consequently the development of human language.

To this end, we try to survey the possible regions on the planet where sea-crossings may have occurred during the last million of years: the Wallacea region between south-eastern Asia and Australia / New Guinea, the Gibraltar Strait and the islands of the Mediterranean Sea, the Southern and South-eastern coastlines of Asia, the Eastern coastline of Africa. Computations of visibility between an observation point and a target location and evolutions of the sea level are taken into account to determine which locations could had been populated by sea-crossings with or without visibility, or on foot during a period of lower sea-levels.

The on-going measurements reveal that many locations, including Japan or islands in the Mediterranean Sea were reachable on foot during several periods of the Pleistocene. The Andaman Islands are demonstrated to represent another example of Homo sapiens' sea crossings with visibility, having possibly occurred before the colonization of Australia. The only example of Homo erectus' sea-crossings seems to occur in the Wallacea region, where sites discovered in the island of Flores prove that Homo erectus had managed to cross a sea gap of around twenty kilometres more than 700,000 years ago (Morwood 2001) (Bednarick 1997). The possible crossings of the Gilbratar Strait, with presence of Homo sapiens in Northern Africa and Homo neandertalensis in today's Spain at the end of the Middle Palaeolithic also raise challenging questions about the interactions between these two species (Hublin 1992).

On the basis of these conclusions, we discuss sea-crossings as a cultural behaviour which appeared early in some human groups, and a possible cultural difference between Homo sapiens and earlier human species based on a greater inclination towards novelty seeking and

discovery in Homo sapiens.

Cultural language evolution: acquisition or usage?

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A central question for evolutionary approaches to language on a historical time scale is what should be considered as *replication* in a linguistic context. There are broadly speaking two possible answers. The *Iterated Learning Approach* (Briscoe, Hurford, Kirby, Lightfoot, Nowak and many others) assumes that languages are transmitted primarily via first language acquisition. On the other hand, researchers from the historical or functionalist tradition like Croft or Haspelmath argue that language change takes place via the language usage of mature speakers. In the following I will argue that the two perspectives are compatible and should both be taken into consideration.

Under the acquisition based approach, the dynamics of language change crucially hinges on the probability that an infant that is exposed to language L_i will acquire language L_j (for arbitrary i and j). Under the simplifying assumption that there are finitely many languages, these probabilities form a square matrix Q. The population dynamics of language change can be approximated by the differential equation (which can be obtained from the corresponding equation in Nowak (2002) if the impact of linguistic behavior on biological reproduction is neglected, which seems plausible on a historical time scale):

$$\dot{x_i} \;=\; \sum_j x_j Q_{ji} - x_i \tag{1}$$

Here x_i gives the proportion of speakers of language L_i in the population.

Under the usage based approach, the *imitation dynamics*—which has been used in Evolutionary Game Theory to model cultural evolution—is a good candidate for a mathematical modelling of language dynamics. Here each pair of languages has a certain utility (which may be determined by functional and social factors like intelligibility, degree of ambiguity, or social prestige). With a certain (low) probability, an individual may give up its language and instead adopt another one. The higher the average utility of L_i, the more attractive it is as target of imitation. The simplest form of this is the *replicator dynamics* (U is the utility matrix):

$$\dot{x_i} \;=\; x_i \sum_j x_j (U_{ij} - \sum_k x_k U_{kj}) \tag{2}$$

If language change may be due both to imitation and to acquisition, we obtain the combined dynamics (b is a positive parameter that is correlated to the birth rate):

$$\dot{x_i} \;=\; x_i \sum_j x_j (U_{ij} - \sum_k x_k U_{kj}) + b(\sum_j x_j Q_{ji} - x_i) \tag{3}$$

A possible application of this combined model is a refinement of the evolutionary analysis of case marking systems I give in Jäger (2003, Amsterdam Colloqium) that is framed within the usage based model (2). Using corpus based estimates of utterance probabilities and a functionally motivated utility function, I came to the conclusion that only four case marking patterns are evolutionary stable: 1. split ergative, 2. differential subject marking, 3. differential object marking, and 4. zero marking. This is too narrow because pure accusative systems like Hungarian or standard Japanese are wrongly predicted to be unstable. The refined dynamics (3) remedies this. It is plausible to assume that it is more likely for an infant to overgeneralize a differentially object marking language to a pure accusative language than the other way round. So while usage favors split systems, acquisition leads to a bias towards pure systems, and both systems turn out to be evolutionary stable.

Costly Signaling vs. Cheap Talk

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The transition from proto-language to modern language began when part of human communication became detached from costly signaling and evolved into a separate channel of "cheap talk." Language is not necessary to signal one's intentions or resource-holding potential (RHP). Those social utilities precede modern languages. Whereas all forms of honest signaling, including both emotional and behavioral cues, are easy to learn (or involuntary) but costly to perform, human languages, dialects, and even "lingos" are costly to learn but easy to perform. Moreover, humans produce false statements as easily as true statements, and while we are adept at recognizing a conspecific's predisposition to cooperate or defect from nonverbal cues, we are inept at identifying factual verbal deceptions. Language is not under selection pressure to honestly signal affect or intention, nor do humans trust language alone in those domains.

This paper reports results from a series of double-blind, anonymous economic experiments utilizing "sudden-death" elimination tourneys of prisoner's dilemma games in which players can opt to "protect" or "abandon" fellow players. Elimination in each round is probabilistic rather than determinate. In the control treatment, players have no communication and are randomly matched in each round. In variable treatments, players are able to advertise for partners who will protect them, either by signaling with 1-word markers or 3-word phrases or sentences, or by offering a share of their stake to any potential partner. Results showed that 1-word or 3-word phrases ("cheap talk") had no significant effect on cooperation or survival, whereas concrete shares ("costly signaling") led to enhanced cooperation and greater success of both the proposers and acceptors.

Language change and social networks

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Sociolinguistic studies have shown that social networks play an important role in stratification of language use, and language maintenance and shift (Milroy, 1980; de Bot and Stoessel, 2002). However, these empirical studies only focus on small scale social networks of local communities, and examine the situation over a short time span. The effect of different topologies of social networks on language change in the long run has been little discussed. While it seems difficult or even impossible to deal with large scale social networks over a long period of time for empirical studies, simulation models serve as an effective alternative methodology.

In recent years, there has been a dramatic growth of interest in complex large-scale networks in various areas (Watts, 1999, 2003; Barab¨¢si, 2002; Buchanan, 2002), triggered by the discovery of several new types of networks, such as small-world networks (Watts and Strogatz, 1998), and scale-free networks (Barab¨¢si and Albert, 1999). It has been found that many complex networks in reality demonstrate several self-organizing characteristics which can not be captured by random or regular networks. Social networks, such as friendship and cooperation, are found to exhibit similar characteristics, which suggests linguistic social networks may be modeled adequately by scale-free or small-world networks.

In this study, we argue that it is important to take into account social networks in simulation models of language change, and to choose an appropriate type of social structure closer to reality. We compare different types of social networks regarding their effect on language change, based on a diffusion-through-learning model proposed by Nettle (1999a). In Nettle¡¯s model the social structure of the population can be considered as a regular network, which is very unlikely to be true in real situations. Our simulation examines more realistic social structures, and finds that the dynamics of language change in populations of small-world or scale-free networks are closer to empirical data than regular or random networks. Nettle (1999b) argues that the rate of language change is unlikely to be constant in populations of different sizes. We re-examine this argument using our simulation model and suggest that a constant rate of change is possible under some conditions. Furthermore, we use the model to study how a regular language change is possible if the change progresses in a lexical diffusion manner.

In the current network models of general interest, the individual nodes are often assumed to have the same internal properties, except for their different connections and different states. We propose that it is necessary to consider the heterogeneity of the individuals in the language community. The data from an empirical study of an on-going sound change in Cantonese show that individuals exhibit a large degree of variation in their language behavior which can not be explained by idiosyncratic linguistic experiences, but rather requires individuals to have different learning styles. We hypothesize that there are at least two types of learning styles, that is, some individuals learn to use both competing variants of a change, while others learn only one variant without accommodating the coexistence of the two. The empirical data

show that the former type of learner (called a ¡°probabilistic learner¡±) is much more frequent than the latter (called a ¡°categorical learner¡±), and the simulation further suggests that the existence of the probabilistic learners provides a much higher chance for language change to complete than what is suggested by Nettle¡¯s (1999a) model in which only categorical learners are assumed.

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Objects of Social Attention: Origins of "You-Me-It" ?

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"You-Me-It" is a triadic interaction, fundamental to language learning, in which co-attention to an object is directed and confirmed (Bruner 1975; Bates 1979). Discussions of the evolutionary origins of adeptness in such interactions are often situated in the context of tool use. In such scenarios, early hominids are described as inventive individuals with the insight and dexterity to modify objects into tools and, in a subsequent phase of their evolution, to learn and pass on such practices through imitation and pedagogy (e.g. Parker & Gibson 1979; Donald 1991). That is, it is generally assumed that the role of "inventor" logically predates that of "demonstrator", since there must first be objects of intrinsic value (e.g. tools for "extractive foraging") worth pointing out to others if the selective advantages of deictic behavior are to accrue. This assumption is apparently supported by studies of contemporary apes, such as chimpanzees (*Pan troglodytes*), who, although evidencing rudimentary tool-making abilities, almost never put effort into directing the attention of others toward their own tool activities (Boesch 1991; Matsuzawa 2001). While the emergence of "You-Me-It" in this context would clearly offer the benefit of facilitating the more rapid learning of tool techniques, our research on social attention in bonobos (*Pan paniscus*) suggests that this may not have been the earliest, or only, context in which such directed attention to objects could have been adaptive.

While wild chimpanzees have a fledgling "tool kit", bonobos are much less likely to make and use tools outside of captivity (although see Ingmanson 1996). However, like chimpanzees, bonobos have complex social relationships, recognize themselves in mirrors, and are adept at gaze-following and social referencing (Savage-Rumbaugh 1986; De Waal & Lanting 1997; Johnson et al. in press). Also like chimpanzees, bonobos (at least those not enculturated by humans) do not tend to explicitly point out or show things to one another (Bard & Vauclair 1984; see Call & Tomasello 1994). However, our micro-analysis of videotapes of bonobos at the San Diego Zoo suggest that these animals may actively use low-value objects (like nesting material or browse) to attract social attention (see also Plooj 1978; Nishida 1980; Tomasello et al. 1994).

As a part of a larger study of social attention in these animals, we have done frame-by-frame analyses of their behavior, scoring relative head and body orientation, gesture and, when possible, focus of gaze. Preliminary results suggest that when an animal positions and, especially, moves an object (to which it, itself, is attending) such that the object clearly breaks the line of the animal's silhouette, that object becomes salient to others. This can be seen in a disproportionate likelihood that the other animal will quickly shift its own attention (i.e. its gaze and/or head orientation). Most of these shifts are toward the individual with the object, but some are shifts away; failure to shift is rare. Furthermore, such object displays nearly always occur when the attention of the second animal is directed elsewhere, especially toward a third party.

These findings suggest to us that such objects may be considered "social currency"; that is, a means of obtaining social, not technological, ends. The social attention that they garner is presumably a desirable commodity, as it indicates a receptivity to subsequent signals and is a common prerequisite of engagement. It can also serve to disrupt an ongoing interaction between others. While not qualifying as a true "You-Me-It" interaction, since no obvious efforts are made by the object-user to confirm and support the ensuing shared attention, such behavior may well represent a rudiment that was subject to further selection for the manipulation of others'

attention. Thus, perhaps, the origins of “You-Me-It” are more about “You & Me” than they are about “It”.

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From monkey calls towards human speech. A neurobiological perspective

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Monkey calls have in common with human speech that they represent communicatory signals produced by the phonatory apparatus. Monkey calls differ from human speech in that their acoustic structure is more or less completely genetically determined, while spoken words are learned by imitation. Phylogenetically, human speech evolved from monkey calls. The question arises of which changes in central organization accompany the evolution from monkey calls to human speech. A comparison of lesion effects, electrical brain stimulation effects and regional neural activity changes on monkey vocalization on the one hand and speech production on the other shows that a number of structures dispensable for monkey call production, are indispensable for the production of human speech. Such structures are, for instance, the sensorimotor cortex, supplementary motor area, basal ganglia, thalamus and cerebellum. Other structures are involved in human speech as well as monkey call production. Examples are, apart from the phonatory motoneurons, the anterior cingulate cortex, the periaqueductal gray of the midbrain and the reticular formation of the lower brainstem. Anatomical studies, furthermore, show that some speech-relevant brain areas are directly connected with each other in humans, but are only indirectly connected in monkeys. An example is the projection from the motor cortex to the laryngeal motoneurons. These findings make clear that speech evolution was accompanied by an extensive reorganization of the neural network underlying monkey call production.

(Un)Masking Selection: from innate to learned signalling and beyond

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One of the unusual features of human language is the degree to which it involves learning. We acquire an enormous amount of information about our native language through early learning, and invest a lot of resources to its acquisition. In return we get a communication system that is uniquely supple. When combined with symbolic reference, a learned system can be rapidly adapted to new uses as our communicative needs change. In addition, learned systems of reference give rise to cultural evolution. We have argued elsewhere that this in turn is responsible for the fundamental components of syntactic structure, the other hallmark of human language.

We can think of the emergence of learning as a major transition in the evolutionary history of human language - a necessary transition from a largely innate simple signalling system to one that enables subsequent evolutionary development. We are left with the question: What caused this transition?

Recent studies by Kazuo Okanoya of a domesticated species of finch provide us with a model for the emergence of learned behaviour on a very rapid evolutionary timescale. The finch has been bred in captivity for 250 years and has a song that is supported to a large degree by early learning. Surprisingly, the feral progenitor of the finch has a far less flexible, more innately pre-specified song. Learning has evolved despite only a short period of domestication. What makes this really remarkable is that the bird was bred for plumage, not song.

In this paper we present a computational model inspired by the finch data showing how learning can replace innate coding of behaviour in the absence of direct selection. We argue that learned behaviour actually emerges when selection is "masked" - in other words, when a feature previously under selection pressure is exposed to genetic drift.

These results suggest that the emergence of learning in the evolutionary history of human language resulted from an alteration in the fitness landscape that reduced selection pressure on an our innate signalling system. As features of the genotype are masked from selection and relinquish control, other previously ineffectual factors can come to influence behaviour. In the finch example, these unmasked influences probably included auditory experience and a variety of social/environmental biases. Thus, de-differentiation can be the first step toward more distributed and flexible behaviour.

We argue that these twin processes of masking and unmasking may have had a critical role in the evolution of our unique biological capacity for language acquisition.

From domain-specific recursion to abstract syntax.

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Life has evolved on the basis of conserved developmental systems that read a ‘universal language’ - the DNA code. Prior to the evolution of speech, subsequent natural selection appears to have produced no further universal languages, nor biological signals combinable in a comparable way. In addressing the second emergence of discrete-combinatorial structure, Hauser, Chomsky and Fitch (2002) contrast two senses of the technical term "Language Faculty" (FL) - "narrow" (FLN) and "broad" (FLB). FLN is the abstract linguistic computational system alone, independent of the concrete biological systems with which it must interact. FLB includes interfaces with sensory-motor and conceptual-intentional systems. Since these are not unusual in nature, the challenge is to explain FLN. The authors view this not as a Darwinian adaptation but as a spandrel. FLN evolved out of a recursion module dedicated to a non-linguistic function such as mind-reading or navigation. In the human case, for reasons unspecified, this became domain-general - whereupon FLN took up its current position as the central component of FLB.

Accepting the argument as a working hypothesis, this paper proposes a context for the breakthrough to FLN. Mind-reading resembles DNA replication and transcription in that no external receiver need be manipulated, persuaded or reassured. All signals, by definition, are internal. When one internal component of a cell or mind communicates with another, genetic interests are irrelevant because they are all the same. With dishonesty not an issue, questions of trust can be set aside. It is quite different when individuals intentionally offer cues to one another’s internal states. Interests here may not coincide, and the costs of deception rise as cooperative investments are made. Even between kin, signals must be reliable to be effective; in demonstrating reliability, signallers must incur added costs. Faced with uncertainty, receivers demand concrete, holistic displays, screening out digital abstractions. Significant variation becomes analog, and such cues cannot be recursively combined.

Such issues might legitimately be ignored were language internal to the individual organism. Noam Chomsky favours this solution: I-language is internal computation. But in that case, why should Logical Form need to interface with Phonetic Form at all? What necessitates any interface between internal recursion and external processes such as articulation, transmission or comprehension? If internal computation were recursion’s original function and also its linguistic function, why invoke "exaptation" at all? Exaptation implies restructuring to serve some novel purpose. Since speech is in fact well-designed to allow thoughts to be shared, this is the suggested candidate. But then communication returns us to social factors, and hence to the problems of conflict and deception from which we earlier attempted to escape.

There is a solution. Language is internal, but not to the individual brain or mind. Just as coinage is internal to a financial system, so language is internal to some rule-governed wider game. No individual can authenticate their own banknotes; neither can they validate their own words. In each case, nothing can happen without securing agreement, collusion being central to the accomplishment of each move. Speech acts, then, are collective hallucinations - neither true nor false - and on that abstract level, mistrust and deception have no place. Instincts are involved - for material exchange on the one hand, communication on the other. But language as such is no more an instinct than is money.

To approach either's emergence independently of its institutional matrix would present as many puzzles as viewing DNA apart from its role in life.

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Abstract submitted to the 5th Evolang Conference

"Symbolic Economies" and the Origin of Language

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The comparison between language and money is recurrent in Western culture (up to Saussure's famous comparison between linguistic signs and coins). More recently, in the 1970's, some philosophers emphasized the concomitant appearance in ancient Greece of specific philosophical categories, and of monetary exchange using struck coins (e.g. Sohn-Rethel); or even described money as a general model for any semiotic process involving the creation of values (Goux).

The question of language origin has dramatically evolved in recent years, giving raise to many competing models, none of which however trying to take into account these homologies, first developed in a merely philosophical and sociological perspective. This is what we intend to do, by linking the emergence of language and the emergence of what we call "symbolic economies". We provisionally define "symbolic economy" as a complex system in which transactions aim at assigning and transferring symbolic values (e.g. values of acts, roles, or even other signs) through a co-emerging semiotic medium. Our guiding intuition is that functions of human languages should be viewed within the social context in which "exogamic" groups co-exist by means of ritualized "protocols" (gift, exchange, alliance, payment, sanction). All these protocols imply an exchange of symbols like objects, gestures, or (proto)linguistic signs, whose symbolic values stem from their involvement in ritualized actions which, on the other hand, cannot be recognized or achieved without the above mentioned symbols.

Although money far postdates language in human history, the use of money reveals social, cognitive and semiotic constraints or resources which presumably are also involved in linguistic activity. The analogy is even more valid if we depart from a strictly utilitarian point of view in economy (Aglietta & Orlean), and a strictly conceptual/referential view, in semantics. Indeed, both money and language provide a "general equivalent" for an open series of occurrences by: (i) elaborating abstract and fictive values in a sensible medium, and (ii) creating a universal reference system, of a fictive character, which regulates all emergent values, including the most basic and individualistic ones. On this viewpoint, the traditional functions of language can be analyzed by analogy to those classically assigned to money (evaluation, diffusion, payment, saving).

The analogy between language and money may however turn out to be spurious if we do not take into account: (i) the archeological and anthropological findings showing various types and functions of "money" in archaic societies, mostly related to the sacred; (ii) the work in theoretical economy describing the concurrent emergence of different "currencies" as a result of a mimetic behavior of agents rather than an application of pre-established values; (iii) the theories in which language activity is primarily considered as a way of evaluating/categorizing actions and roles, and of 'buying' social position by affording certain symbolic values.

In summary, we (i) describe analogies between functional roles of money and language in human transactions, (ii) present a non-utilitarian "symbolic economy" framework in which such analogies become more effective, (iii) discuss some of the elementary transactions on which this kind of symbolic economy could be based, and (iv) try to clarify the relationship between this speculative model and grammatical categories of human languages (e.g.case roles).

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Socially meaningful vocal plasticity in Campbell's monkeys

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Compared to other primates, human vocal behaviour is exceptionally flexible, generating somewhat of an evolutionary conundrum. What are the evolutionary origins of the human vocal flexibility in the primate lineage? We present data on Campbell's monkey vocal behaviour, which show that, although very subtle, important acoustic flexibility is present and determined by social factors. Previous work has shown that in this species, females frequently exchange particular vocalisations, the combined-harmonic calls, during social interactions. These calls can be classified into distinct subtypes and one of them, the CH6 subtype, is highly variable in its acoustic fine structure. Females differ in the number and types of CH6 variants they produce at any given time. Some variants can be produced by more than one female, indicating that females share variants. A female's pattern of variant production and variant sharing can change in response to important social events, even during her adult life. Here, we provide observational and experimental evidence to further explore the communicative function of this intriguing vocalisation system. First, our analyses showed that older individuals were more likely to elicit vocal responses from other group members than younger ones. Responses typically occurred within less than a second, suggesting that individuals answered each other's calls. In some cases, responding individuals matched their own call subtype to that of the initiating animal. Second, we conducted a playback experiment to investigate whether the CH6 variants used in vocal sharing were meaningful to recipients. We compared the group's response between currently and formerly used variants, i.e. calls produced by the same individuals at present or several years ago. We found that current, but not former, variants reliably triggered a natural exchange of calls in recipients. Instead, former variants caused a temporary decrease in calling rates, demonstrating that the monkeys discriminated these exceedingly subtle acoustic differences and that they were socially meaningful to them.

Social communication in orangutans (Pongo pygmaeus): Use of gestures and facial expressions

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Keywords: Pongo pygmaeus, communication, gestures, facial expressions, flexibility

Studies of animal communication systems are essential to understand the evolution of human language. The majority of research focused on vocal communication (Seyfarth, 1987; Snowdon, 1988) what seems to have derived from the analogy to human language (Tomasello et. al, 1997). Other authors have suggested a gestural origin of language (Hewes, 1973; Corballis, 2002; Arbib, 2002). Grigor^Òeva et. al (1987) proposed that the evolution of gestural communication in primates proceeded from a stage involving a majority of tactile gestures to an increasing number of visual gestures. Therefore monkey species should use a wider repertoire of tactile gestures while great apes should use a wider range of visual gestures. The social communication of orangutans is only poorly investigated in contrast to the African great ape species (Goodall, 1986; Tomasello et. al, 1989, 1997; de Waal, 1988; Kano, 1992; Tanner et. al. 1996; Pika et. al, 2003). Some authors suggest that despite their semi-solitary lifestyle orangutans use a wide range of vocal signals and gestures (Kaplan and Rogers, 2000; MacKinnon, 1974) while others argue that they might have lower communication skills (Bennett, 1998). In addition, their natural habitat seems to predict the importance of tactile or vocal signals rather than visual signals (Maestripieri, 1996). The present study is the first systematic investigation of the communicative repertoire of Sumatran orangutans (Pongo pygmaeus) with focus on gestures and facial expressions of two groups of captive orangutans. The main goals were to analyze the signal repertoire with respect to 1) the number and frequency of signals (tactile, visual and auditory gestures, facial expressions), 2) the variability of individual^Òs repertoire as a function of group, age class and gender, and 3) the flexibility of use with respect to ^Ñmeans-end- dissociation^Ò (Bruner, 1981) and adjustment of signals depending on the attentional state of the recipient. 17 individuals (10 adults, 3 subadults, 2 juveniles, 2 infants) were observed using a video camera to record a total of 170 hrs (10 hrs of ^Ñfocal-animal-sampling^Ò per individual). The results show that orangutans use a multifaceted signal repertoire with a majority of visual gestures characterized by flexibility of use and sensitivity to the attentional state of the recipient. The findings are discussed in terms of orangutan ecology, social structure and the evolution of gestural communication comparing the results with recent studies of social communication in siamangs (Liebal, in press) and African great ape species (Tomasello et. al, 1994, 1997; Pika et. al, 2003; Pika et. al, submitted).

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Consequences of the Exaptation of Dialect Diversity for Social Marking

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The application of dialect variation to social marking - allowing members of groups to easily identify outsiders - has been noted in many studies, although there has been some debate over the extent to which it has driven language change and variation. Dunbar (1996) and Nettle (1999) argue that the adaptive benefits of social marking promote the evolution of dialect diversity, while Milroy (1993, p.215) argues a complementary point that a social benefit arising from dialect differences must exist for significant language changes to occur as readily as they do.

We have previously presented counter arguments that it is more likely that social marking is, in effect, an exaptation, a novel use of a spandrel formed by the natural emergence of dialect diversity, such diversity being a consequence of the acquisition of language in spatially distributed populations (Livingstone, 2000).

Assuming that diversity will emerge regardless of adaptive benefits, it remains to be answered how the adoption of dialect differences to act as social markers might influence the continued evolution of dialects and linguistic diversity.

Here we present the preliminary findings of the effect of social influence and marking on computer simulations of the evolution of vowel systems in spatially distributed populations. We use de Boer's (2000) phonological model for the individual agents, within a population whose arrangement, replacement and migration patterns are based on Nettle's (1999) model. This allows for ready comparison against Nettle's findings, as well as matching closely to a much earlier model - one used over a century ago in a thought experiment which supposes, "a large plain covered with villages of equal size and independence at equal distances" (Sweet, 1888, p.52). We find that with no social influence in the model a dialect continuum is formed - just as Sweet anticipated. We then add social influence as a factor in the acquisition of vowel systems and compare the dialect diversity found against that found when social influence has no part to play.

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A Life History Approach to the Evolution of Language

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It has long been asserted by linguists that *Homo sapiens* is the only species that has language, but only recently recognized, in other disciplines, that humans alone have a childhood---a distinct and relatively stable interval between infancy and the juvenile period that follows---and a period of adolescence. I propose that all ontogenetic stages, from infancy to childhood, juvenility, and adolescence, played a role in the evolution of language, and that language, in turn, influenced one or more stages. It is assumed that selection operated at sexual maturity, favoring those who approached adolescence with an unusual command, initially, of vocal behavior, later vocal and verbal behavior. Sexual selection of competitive vocal-verbal behavior produced a pattern of sexual dimorphism that has previously escaped notice. Individuals with longer intervals between infancy and sexual maturity achieved greater expressive abilities than others, and held the advantage in critical within-group competitions. Childhood and juvenility are thus seen as transitional periods in which linguistic "content" is available but not yet fully operational, and a host of critical pragmatic and performative behaviors are still developing. According to the life history perspective presented here, the insertion of new ontogenetic stages in the hominid line served to advance, and now help scholars to date, the evolution of language. Life history appears to offer a new way of thinking about the evolution, development, and nature of language, one that integrates linguistic content with competitive and performative applications of language, by voice and speech.

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Language is Not Just for Talking: how linguistic labels help in representing the world.

In addition to its communicative functions, there is both intuitive agreement and much experimental evidence that language shapes thought (Bowerman & Levinson, 2001). Language allows us to form complex chains of thoughts (Carruthers, 2002; Varley, 1998) and it facilitates retrieval of items from memory (Malt, et al. 2003). There are recent suggestions that experience with natural language is crucial to forming a theory of mind (de Villiers & de Villiers, 2000), perhaps through its reliance on perspective-taking (MacWhinney, submitted).

The present work looks at a basic property of language-the idea that things, properties, and events can be labeled, and examines how category labels can aid in forming conceptual representations. The prediction is that labels will be useful in domains containing exemplars close together in perceptual space, in noisy domains, and domains that are not linearly-separable based on their perceptual properties. In effect, labels serve to bind features and enable one to infer properties about a given scene based on other exemplars that share the same category label. Crucially, this view of category labels does not require them to be a part of a shared system of communication. This supports the view that an important force in language evolution was the idea that entities and events could have labels independent of their perceptual properties. This allowed humans to form robust representations of domains that are poorly structured with respect to their perceptual properties. Feedforward neural networks were trained to map a series of input vectors to identical output vectors (auto-association), and in "cleaning up" noisy exemplars. The inputs were organized into categories organized around two prototypes. Label conditions associated each exemplar with one of two category labels. The simulation results confirmed the hypotheses. Labels were particularly useful in cleaning up noisy exemplars ($F(1,76) = 28.78$ $p < 0.001$), for items that clustered closer together compared to those that were more separated ($F(1,76) = 8.65$ $p < 0.004$), and for forming representations of exemplars organized into non-linearly-separable category structures ($F(1,76) = 4.76$ $p < 0.03$). Networks that were trained with labels outperformed the no-label ones _even when the labels were not presented at test_. Conversely, labels did not help in forming efficient representations when the networks could perform the task perfectly well by simply relying on the perceptual properties of the stimuli.

These results speak to the controversy surrounding the study of language-thought relations. Proponents of linguistic relativity (e.g., Boroditsky, 2001) have argued that specific languages shape thought by highlighting and downplaying certain dimensions. Critics argue that these effects are limited to linguistic tasks, and are dissociable from tasks not mediated by language (e.g., Munnich & Landau, 2003). The present work suggests there is a continuum of linguistic effects. Domains heavily dependent on perception may indeed be largely independent and dissociable from language e.g., speakers of Dani, a language with only two color terms and no words for basic shapes have no problems differentiating colors or forming categories of shapes (Rosch, 1973). At the other end of the continuum are numbers and complex spatial relations that may require recourse to language not just for expression, but also representation (Spelke & Tsivkin, 2003). If Spelke et al's suggestions are correct, there may not be a way to represent the concept of thirty-nine, or "to

the left of the blue wall" without language. The domains explored in the present simulations constitute the middle-ground-for which representations can be formed without labels, but which significantly benefit from their presence. Our next step is to test these hypotheses directly in humans through a series of experiments with young children, divided into label and no-label groups.

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Why Irregulars Make Sense: simulating the emergence of exceptions.

The English past tense is a quasi-regular system, in that many of the irregular verbs share characteristics with regular items. Among high-frequency exceptions in particular, several have the regular /d/ or /t/ ending but with either a reduction of the vowel (did, said) or a deletion of a stem consonant (had, made). The tendency to adhere to the phonology characteristic of the regular forms suggests that so-called irregular verbs reflect a joint influence of the systematic past-tense pattern captured in fully regular items together with a pressure to be short or simple. In the present work, we adapt familiar neural network formalisms to show how quasi-regular forms arise if the phonological content of word forms are constrained (a) to support accurate communication of the word's meaning and (b) to be simple. The simulations provide a framework employing distributed representations and graded constraints, which may provide a useful basis for investigating language structure and language change.

The present work attempts to provide a functionalist view for morphological irregularity contrary to the standard view of "irregular alternations [being], by definition, functionless" (Greenberg, 1957, p. 65). Namely, morphological irregularity may arise to reduce the phonological complexity of frequent words. We draw on the optimality theory approach of Burzio (2002) and the framework of minimum-description length (Zemel & Hinton, 1994) to study how phonology changes over time.

Among questions addressed by the present work is why it is that cross-linguistically, it is the most frequent words that are morphologically irregular. We argue that this is because production costs are greatest for frequent words---these are the word for which the costs have to be paid most often. We formalized this notion by adopting the framework of minimum-description length. Given the goal of communicating a message from one individual to another through a sequence of phonemes, we can express the sending/receiving cost of various messages as the sum of two terms: the phonological cost---paid to generate or perceive the phonological form, and the reconstruction error---the ease or difficulty of recovering the semantics from the phonology. Compositionality (morphological regularity) minimizes the reconstruction error by, for instance, predictably associating an affix with a semantic notion of pastness. On the other hand, quasi-regular morphology increases the reconstruction error, but can minimize the phonological cost by pushing the word to a simpler phonological representation. The reconstruction cost constrains the changes to phonology such that words can only change over time insofar as the changed forms will be understood by the other speakers of the language. As part of the current work, we explored how a "community" of speakers can implement such a constraint. Neural networks faced with these pressures, mirror the types of changes seen in natural language.

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Semiotic Combination in Pan: Evolutionary implications of proto-syntax

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Over twenty years of research at the Language Research Center have demonstrated that bonobos can learn to comprehend spoken English at the level of a two-and-a-half year old human child without explicit training (E. Sue Savage-Rumbaugh, 1986; E. Sue Savage-Rumbaugh, McDonald, Sevcik, Hopkins, & Rupert, 1986; E. Sue Savage-Rumbaugh et al., 1993; E. Sue Savage-Rumbaugh, Shanker, & Taylor, 1998). In addition, these bonobos could utilize visuographic symbols (lexigrams) on a printed keyboard to communicate with researchers. Earlier research with chimpanzees (Pan troglodytes) in more formalized language training programs had been less successful (Gardner & Gardner, 1969; Hayes, 1951; Kellogg & Kellogg, 1933; Rumbaugh, 1977; E. S. Savage-Rumbaugh, Rumbaugh, Smith, & Lawson, 1980; Terrace, 1979). Because the research at the Language Research Center included a different species - bonobos (Pan paniscus) and a different rearing environment (including extensive early language enrichment, but no formal training) a co-rearing study was initiated. Rearing a bonobo (Panbanisha) and a chimpanzee (Panpanzee) together demonstrated that the primary source of earlier chimpanzee-bonobo communication differences was rearing environment, rather than species-based genetic differences (Brakke & Savage-Rumbaugh, 1995, 1996; Williams, Brakke, & Savage-Rumbaugh, 1997).

This paper focuses on the spontaneous lexigram and gestural symbolic productions of these co-reared apes and compares them to another symbol-competent bonobo and productions from human researchers who were the apes' primary caregivers. Specifically, we report on two-element combinations (two lexigrams or one lexigram plus one gesture) produced by the apes throughout five months of the study period. All productions during the study period were instances of spontaneous two-element combinations, which were then coded according to their semiotic functions, following the procedures in Brown (1973) and Greenfield and Savage-Rumbaugh (1990; 1991). The results demonstrate the construction of communicative conventions: shared norms for combining symbols that were shared by either the two co-reared apes, all three language competent apes or one of the apes and the researchers. For example, all three apes and the human researchers were more likely to order an action before an agent, rather than an agent before an action ("open cooler" rather than "cooler open"). These shared norms were statistical, not absolute, which is true of human children as well (e.g., Bowerman, 1973; Goldin-Meadow & Mylander, 1984). Ordering conventions applied to combinations consisting of lexigram plus gesture, as well as combinations consisting of two lexigrams. These findings are in contrast to earlier reports of language-trained apes which did not find ordering conventions in their productions (Terrace, Petitto, Sanders, & Bever, 1979, 1980).

Additionally, a bonobo shared more communicative conventions with his co-reared chimpanzee than with another bonobo who had not shared the same rearing environment - emphasizing the importance of social interactions and early environment in forming communicative conventions, over species-specific predispositions. However, this study offers no evidence to support the knowledge of formal syntactic structure in any of the apes. It is therefore possible that the ability to create communicative conventions at the level of proto-syntax was present in the common ancestor of chimpanzees, bonobos, and humans five million

years ago (Byrne, 1995) and subserved the subsequent evolution of communication in each species (Gannon, Holloway, Broadfield, & Braun, 1998).

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Baby Talk and the Origin of the Word

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Falk (Behavioral and Brain Sciences [BBS], in press) offers a plausible scenario regarding the communicative context for the first spoken words. Early hominin mothers, she argues, needed to put down their babies, who had become unable to cling to them, while foraging. The resultant need for parental care at a distance created selection pressures for elaborating the dyadic vocal communication pattern, thus helping to account for the sheer volubility of modern hominins compared with their nearest relatives. The repeated occurrence of particular vocal episodes within the mother-infant communicative dyad could have induced a participant to link a specific vocalization with a recurring aspect of the context, as a word requires.

We note conducive characteristics of the mother-child dyad: (1) a non-threatening environment, with intimacy allowing structured communicative modes, and (2) highly focused attention. The communication patterns would be, as they are now, stereotyped, simple, and relatively small in number.

Sound patterns of first words, perhaps formed in this context-baby talk words-may have shared two properties of speech that infants and languages, including Creole languages, share today-the universal consonant-vowel (CV) form and a biomechanical constraint on amount of intrasyllabic tongue movement (MacNeilage & Davis, BBS, in press). This constraint takes three forms: Coronal (or tongue-front) consonants co-occur with front vowels, dorsal (or tongue-back) consonants co-occur with back vowels, and labial (or lip) consonants co-occur with central (neutral?) vowels (MacNeilage & Davis, Science, 2000).

Falk suggests that nasal demand-vocalizations, (e,g, "m-m-m-") observable today when the infant is separated from the parent, (Goldman, J. Child Language, 2000) may have given rise to a first word. The mother could have surmised "This sound stands for me." Consistent with this proposal, all the baby-talk words for "mother" in a corpus of 6 languages presented by Ferguson (American Anthropologist, l964) have nasal consonants. Strikingly - and this suggests a systematic cross-linguistic communicative contrast in baby-talk words-all the baby-talk words for "father" have only oral consonants. But whereas the nasalized demand-cries of modern infants occur in the prebabbling stage and are consequently quasi-steady-state vocalic forms, baby-talk words feature the CV syllable and the biomechanical constraint against intrasyllabic tongue movement (hence "mama" and "papa"). Nasality (and orality) might have been incorporated into protosyllabic CV strings in the first baby-talk words because these cyclicities may have constituted the core of the already existing vocal-grooming repertoire postulated by Dunbar (BBS, l993). The implication of this is that the first imitation in the evolution of words was a partial imitation of infant vocalizations by the female adult-an imitation of nasalization incorporated into CV forms, in what was, in effect, a self-naming operation.

The likelihood that baby-talk forms were a source of parental terms in languages proper is indicated by Murdock's finding, in a corpus of 474 languages (American Anthropologist, l959), that the first syllable of 78% of maternal terms had a nasal consonant, whereas the first syllable of 66% of paternal terms had an oral consonant. Predictably, from our standpoint,

these first (predominantly CV) syllables of parental terms also have the intrasyllabic biomechanical constraint on tongue movement.

If parental terms in languages have additional phonetic properties of baby-talk words, this would provide further evidence for a phylogenetic link between parental terms in baby talk and in language proper. The baby-talk forms, like other infant vocal forms, tend to involve syllable reduplication (e,g, "mama"), whereas languages proper avoid it. Thus baby talk has intersyllabic as well as intrasyllabic biomechanical constraints on tongue movement. That is, the tongue tends to maintain its position across as well as within syllables. Intersyllabic biomechanical constraints are absent in modern languages, in which successive syllables tend to be different. We are currently investigating the hypothesis that parental terms in languages tend to have more syllable reduplication than other words of languages, and, unlike other words of languages, have the intersyllabic biomechanical constraint on tongue movement, as well as the intrasyllabic constraint.

Are gestures without language more transparent than gestures with language?

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Many theorists have argued that the earliest symbols in the evolution of language must have had transparent referents in order for the interlocutor to understand the meaning of the communicator (e.g., Hewes, 1976). In conjunction with the assumption that gestures are (or can be) transparent, this claim has led many researchers to propose that gestures provided an ideal transitional medium into fully developed language (e.g., Armstrong, 1999). If so, then gestures in the absence of language may be more transparent that gestures with language. To test this hypothesis, we examined the gestures used by signers and speakers. Signers have to stop signing in order to gesture while speakers can speak and gesture simultaneously. As a result, signers[1] gestures must carry the weight of the meaning communicated (since no simultaneous linguistic stream is possible) so may be more transparent than the gestures of speakers. We showed 60 gestures of signers and speakers to 33 naïve English speakers and asked them to guess at the meaning of the gestures. Preliminary analyses suggest that the naïve subjects were more likely to guess the meaning of signers[1] gestures correctly than those of speakers ($c2 = 69.6$, $p<.005$). These results suggest that when gestures are used alone to convey meaning, they become more transparent.

Evolutionary robotics experiments on the emergence of communication

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In the computational study of language evolution, new approaches are sought that use more plausible and realistic cognitive models. These should also take data on human and animal communication into consideration (Tomasello, 2002). Cognitive robotics uses embodied and situated robots where communication results from the dynamical interaction between its physical body, the nervous and cognitive system and the external physical and social environment (Beer, 1995; Steels, 2003). Recently, evolutionary robotics (Nolfi & Floreano, 2002; Marocco et al., 2003) has been proposed to model language evolution. In this paper, new experiments are presented based on a recent model of the emergence of sensorimotor categorization (Nolfi & Marocco, 2002). Agents use proprioceptive information to actively explore the environment (using a three-segment arm) and build sensorimotor categories of object interactions (e.g. touch a sphere, avoid a cube). In the new simulations, robots also share a lexicon to communicate about the objects in the environment. The environment consists of an open three-dimensional space. The arm and its interaction with objects are modelled by means of a rigid body simulator called Vortex. Initially, the evolutionary robotics model was used to run a series of experiments on the role of various social and evolutionary variables in the emergence of shared communication. The first independent variable of the experimental design is the selection of speakers: each agent receives communication signals solely from its own parent or from any individual of the population. This looks at the role of different social groups of speakers in facilitating shared communication. The second independent variable is the time period in which communication is allowed: agents can communicate right from the initial random generation or only after the pre-evolution of the ability to touch/avoid the two objects. Through this variable it will be possible to investigate the initial behavioural and cognitive abilities necessary to evolve communication. The simulation results show that populations evolve stable shared communication (i.e. using two different signals are produced for the two different objects) mostly when the parents act as speakers and when signalling is introduced in the second stage (Marocco et al., 2003). Additional analyses of results support the following findings: (a) the emergence of signalling brings direct benefits to the agents and the population, in terms of increased behavioural skill and comprehension ability (but the agents' fitness does not assess the ability to communicate well); (b) there is a benefit in direct communication between parents and children, not only because of kinship mechanisms, but also because parents produce more stable and reliable input signals; (c) the pre-evolution of good sensorimotor and cognitive abilities permits the establishment of a link between production and comprehension abilities, especially in the early generations when signalling is introduced. This model was extended to study the emergence of structured lexicons. Some simulations have looked at the emergence of different types of signals referring to names of objects and actions. These can be related to the linguistic categories of nouns and verbs in a broad sense in which nouns and verbs could be viewed as mental categories to represent objects and actions within the process of interpretation of the world (Pinker, 1994). In addition, this kind of approach can give insights on the fact that the meaning of a word is not simply related to the real object to which the word refers, but more

basically to the way in which the word affects the behavior of the hearer (Wittgenstein, 1953). This supports the idea that language could arise in social negotiation of practical and strictly finalized situations. Further extensions of this robotic model include the ontogenetic learning of language, the use of multi-word utterances, and the integration of vision and language. New simulations will focus on the evolutionary transition from simple communication systems to syntactic languages.

The differentiation of lexical and postlexical processes in the evolution of the grammatical category 'word'.

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In this talk I take up the question of the evolution of the category 'word'. Much work on the evolution of language assumes this category as a pre-adaptation to the development of true grammar (i.e. in connectionist modeling studies (Kirby 2002)), yet it is, itself, a complex grammatical entity (both phonological and morphological). Furthermore, in discussions, some have suggested that an elaborated phonology is a later development in human language (Hurford 2003). I will argue that opposite is likely to be the case: that phonology is likely to be essential to the development of the category 'word' from the earliest stages, and that the development of the category 'word' is highly likely to be coterminous with the development of syntactic grammar, and not prior to it. That is to say the category 'word' is not by definition a 'less complex' entity, but indicates that all the pieces of the grammar are likely to be in place.

The argument presented here rests on two aspects of the hypothesis: statistical learning and the differentiation of lexical and postlexical processes in modern grammars and the essential duality of patterning associated with this distinction.

Significant to the grammatical category 'word' is the fact that there are units smaller than morphemes that are meaningful; that is the sounds (or effects / features) are that are legitimate combinatorial units, and those that *for a given system* are not. I will demonstrate this pattern duality with field data from two phenomena, pitch and duration. Pitch may be used lexically (tone) and postlexically (intonation), sometimes both within the same system (Ladd 1996), yet it is only the lexical tone that can be used to build meaning units. Likewise, while attempts exist to find meaning units within intonational groups (Beckman & Pierrehumbert 86) and to assign meaning to intonational groups and sub groups (Ward and Hirschberg 85), intonation and its parts remain qualitatively distinct from the lexical pitch or tone. The same is true of duration, which may be used as a meaningful unit in the phonology in a length contrast, or it may be used in the larger domain, postlexically, such as final lengthening. Recent studies in online speech processing have shown that listeners are able to distinguish these uses of duration well enough to influence word recognition (Crosswhite et al 2001). However, crucially, at the phonetic level, it is not possible to determine what the effect or status of an occurring duration fact or pitch event is. Independent of its role in the grammar, pitch is fundamental frequency of the voice as it rises and falls throughout the utterance, and duration is a raw score. It is higher level organization that determines the actual function of these phenomena in the grammar. Uncovering the phonemes and words of a language in fluent speech requires building a contrast set that reflects minimally this duality of patterning.

The second aspect of this hypothesis starts from MacNeigle's (1998) frame-content theory of syllable structure, which argues for a structural hierarchy based in lateralization sufficient to ground the development fine oral articulations within the frame of a primitive call, I will argue that the increasing complexity of articulation plausibly developed from pressure to increase 'meaningful' sound features as distinct from those that are not. Saffran's work on statistical learning suggests that the output of pattern recognition processes in humans is constrained by prior generalizations and/or existing knowledge bases (Saffron 2002). If this is the case, one quite plausible preadaptation hypothesis for human language is the need to differentiate between sounds and features that are associated to meaning units and those that are not. The existence of meaning units such as calls indicates a distinction between call and no-call sounds. An increase in call learning or call meaning may plausibly pressure an increase in the complexity of articulations that can be *used* in meaningful ways, in much the same way that complex inventories in contemporary languages (Maddieson & Lindblom 1988) often co-occur in what Trubetskoy called 'wasteful' languages, that is languages with severe phonotactic constraints on the distribution of these contrasts , such as Athabaskan (McDonough 2003) or Ju|'hoansi (Miller–Ockhuizen 2000).

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Evolution and the Two Phonologies

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Evolutionary Linguistics has recently considerably raised its profile; but although many linguists now see the Evolution of Language as a locus of interesting work, the results of evolutionary research are still typically seen as irrelevant to colleagues working in 'mainstream' synchronic linguistic theory. In this paper, I shall provide arguments from phonology to show that evolutionary linguists can now provide insights which are of considerable value and importance for other areas of linguistics, and that these can no longer be ignored.

There is a long-standing and well-known division between segmental phonology, which deals with the properties and interactions of vowels and consonants, and suprasegmental phonology, which focuses on higher-level units like syllables, feet and intonational phrases. It has long been recognised that certain phonological models provide enlightening accounts of segmentals but have little to say about suprasegmentals: this would be true, for instance, of Autosegmental Phonology and Articulatory Phonology. Conversely, there are theories, like Metrical Phonology, which deal more than competently with suprasegmentals, but do not contribute to our knowledge of segmentals. This division of labour was tacitly accepted by many phonologists until recently, when the situation came to a head with the development of Optimality Theory. OT deals in an exemplary way with suprasegmentals like stress and syllabification: but an extension of this strongly universalist, constraint-based approach to segmentals necessitates problematic additional machinery in a model which was initially attractive precisely for its reduction of theoretical apparatus.

How, then, are we to resolve this phonological challenge? If phonology were really a single discipline, then successful models ought, counterfactually, to be able to handle both subparts. On the other hand, arguments for a further-reaching division between the traditionally-recognised subareas must be motivated by evidence from outside phonology itself, to avoid circularity. In this paper, I shall argue that there is a deep division between these two phonologies, which I shall refer to as prosody and melody, and that this division has its roots in the evolution of language. The prosody-melody division is still reflected in evidence from areas as diverse as primate vocalisation; phonological disorder; connections of intonation with gesture and emotion; and brain lateralisation. All this suggests that prosody represents an older continuation of a pre-human system, while segmental phonology has developed considerably more recently (and, incidentally, that prosody is therefore susceptible to analysis using innate constraints specific to language, whereas melody is not). As well as reviewing the evidence for this distinction, I shall argue that prosody and melody can be differentiated clearly. Some phenomena, like stress and intonation, are clearly prosodic; others, such as place of articulation features for consonants, or lexically contrastive tone, are equally obviously melodic. However, I shall show that even apparently ambiguous phonological features, such as length, can be divided into prosodic and melodic expressions. This prosody-melody distinction has very considerable implications for phonological theory, but rests substantially on evolutionary argumentation.

The Ruhlen's "mother tongue" theory subjected to the test of probabilities

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In some approaches, the demonstration of a relationship between languages can rely on finding words of similar phonetic shape and roughly equivalent meaning in the languages in question. Among such approaches, the Multilateral (or mass) comparision is the best-know : “looking at (…) many languages across a few words ‘rather than’ at a few languages across many words” (Greenberg, *Language in the Americas*, 1987 : 23), where the lexical similarity shared “across many languages” alone is taken as evidence of genetic relationship. For about fifteen years now, Merritt Ruhlen’s works in genetic typology of languages, based on multilateral comparisons of sound shapes and meaning similarities for all the the languages of the world, have tried to validate the existence of global roots. Recent advances in biological taxonomy serve to confirm this author’s classification of macro-families, and by implication, monogenesis of all languages. With *The Origin of Languages. Studies in Linguistic Taxonomy* (1994) and *The Origin of Languages. Tracing the evolution of the mothertongue* (1994), he gave further data supporting his thesis. According to him, his theory is backed up by a methodology which enables him to look for and find phonological and semantic equivalencies between words of different languages. In the end, these equivalences enabled him to make comparisons from a set of 32 families. He finally proposes 27 global etymologies and, for each of these mother tongue roots, the provides the most general meaning and the phonological shape

But in order for these global etymologies to be accepted, it must beshown that the similarities observed could not have arisen by chance. That is to say, it must be shown that the null hypothesis can be rejected. We demonstrate, by a single application of probability theory, that the world roots proposed by Ruhlen for a Proto-Sapiens language are the result of random chance. The nul hypothesis cannot be rejected. The author used too few roots, too many equivalent meanings, too many languages per family and too many phonological equivalences for a too small number of different phonological shapes.

Language emerges only in kin-related groups or if it used to talk to oneself

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Language requires the co-evolution of both speakers and understanders. The ability to speak, i.e. to produce useful signals, is useless unless there are individuals that respond to the signals appropriately and, vice-versa, the ability to understand signals is useless unless that are individuals that produce useful signals that systematically co-vary with specific aspects of experience. This implies that if speaking is advantageous for the receivers of signals but not for the individuals that produce them, it is not clear how language may have evolved.

Human language is quite unique among animal communicative systems in that it is often used to inform conspecifics about aspects of the environment. It is an open problem whether this use of communication was the principal function for which human language evolved [Bickerton, 2002] or language evolution started for more social reasons (such as facilitating social interaction and social coordination; cf. [Knight et al., 2000], [Dunbar, 1996]). In any case, the evolution of language for informing conspecifics is something that must be explained in that when an individual uses language to inform a conspecific about some aspect of the environment, the advantages for the hearer are clear but those for the speaker aren't.

We describe a set of simulations in which a population of individuals lives in a world containing both edible and poisonous mushrooms, with each individual mushroom being different from all others [Cangelosi & Parisi, 1998]. To survive and reproduce an individual must categorize encountered mushrooms as edible or poisonous and respond by approaching and eating the edible mushrooms and avoiding the poisonous ones. The behavior of the individuals is controlled by a neural network. Input units encode the perceptual properties of encountered mushrooms and heard signals; output units encode movements for displacing oneself in the environment and for producing sounds. The networks' connection weights are found using a genetic algorithm.

If the sensory capacities of the individuals are spatially restricted such that distant mushrooms can be localized but not recognized, an individual is forced to approach all mushrooms until a mushroom is sufficiently near to be recognized as edible or poisonous. This of course is not very efficient. If a conspecific which is nearer to a distant mushroom produces a signal which co-varies with the mushroom's category, hearing the signal would allow the first individual to approach only edible mushrooms - with a clear increase in efficiency. However, this is a situation in which the production of useful signals benefits the receivers of signals but not their producers. Hence, language should not emerge in these circumstances. Our simulations show in fact that in our simulation scenario language does not emerge if speakers and hearers in linguistic exchanges are randomly selected from the population but it does emerge if the speaker and the hearer are (at least some of the times) genetically similar individuals, i.e., if they are kin. This result is consistent with previous work ([Ackley & Littman, 1994] [Oliphant, 1996]) and might suggest that language (or, at least, language for informing other individuals about the environment) has emerged within small groups of kin-related individuals rather than in larger communities of unrelated individuals.

However, even in its early evolutionary stages language may have had not only a social function but also an individual one: to talk to oneself,

for example as an aid to memory. In talking to oneself the same individual is both speaker and hearer. Hence, speaking and understanding must necessarily co-evolve. In another simulation we show that language evolves even if speakers and hearers in linguistic exchanges are genetically unrelated individuals provided that the hearer repeats to itself heard signals in order to keep information about mushrooms in its memory.

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In Search of Inflection

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Previous work (Moy and Manandhar, 2003) describes an attempt to demonstrate the emergence of case in a population of minimally equipped learning agents, based on Kirby's "Iterated Learning Model" (Kirby, 2000). The emergence of grammars with a primitive form of case was demonstrated: separate noun categories to express subject and object of a sentence. However, category types are not strongly restricted to a single syntactic role, nor are they inflectional i.e. "subject" and "object" forms of a particular noun can not be broken down into common stem plus affix. These limitations were deemed to be due to the details of the model employed.

The current work is an attempt to address these limitations. The semantic representation used for utterances made by agents in the original simulation is a vector in which thematic role is implied by position, for example [loves, john, mary] indicates that the predicate (in the first position) is "loves", the agent (in the second position) is "john", and the patient (in the third) is "mary". However, the parts of speech produced by making generalizations between utterances are independent of position, and thus independent of thematic role. If a rule is created indicating that the string "j,o,h,n" has the meaning "john", it does not specify whether this string represents agent or patient in the utterance in which it was observed. Thus noun categories cannot effectively be restricted to expressing a single thematic role, which might prove a disadvantage in attempts to simulate the emergence of a proper case system.

The semantic representation was therefore modified to give it a nested structure, in which each element specifies explicitly both its thematic role and its value, so that the vector [loves,john,mary] becomes [[pred,loves],[agt,john],[pat,mary]]. The system was modified to handle these nested structures, and to be able to make generalizations between parts of speech as well as between sentences. Thus, once a substring meaning [agent,john] and another meaning [agent,pete] have been induced, any similarity between the two can be attributed to the morpheme specifying that the noun is an agent.

However, the original model induces grammars from its input by making generalisations on the minimal differences between strings. Therefore, if presented with two strings "johnlovesmary" and "johnloveskate" the minimal difference between the two strings, the substrings "mary" and "kate", is attributed to difference in meaning. This poses problems for languages which incorporate inflectional affixes indicating case: these inflections will be the same in every sentence, and thus will not be noted. We will describe current work to investigate whether the emergence of inflectional affixes can be encouraged if the inducer is rewritten to look at minimal ~similarities~ between strings (rather than differences), which will allow inflections to be captured when a noun is learnt, and used in conjunction with the new nested semantic representation described above.

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``The effect of fitness in the emergence of creole''

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We report results relating to the role of fitness in the emergence of creoles. The framework of population dynamics has become involved in language evolution in recent years, the goal being to establish a mathematical and evolutionary theory of language. The language dynamics equation proposed by Nowak et al. [1] is representative of this effort. We have revised their model to be more realistic, in order to study the emergence of a creole in the context of population dynamics. Our prime revision is that the transition rate between languages is sensitive to the distribution of languages in the population at each generation. In addition, we introduce an exposure probability term, which determines the degree of influence from other languages during acquisition. Using this approach, we have previously shown the process of the emergence of a creole [2] and the conditions on similarities among languages required for a creole to emerge and be dominant [3].

In these models, and those of Nowak et al., it is assumed that language speakers bear offspring in proportion to their success at communicating (their fitness). However, in the real world case creoles do not emerge because creole speakers have more offspring than speakers of other pre-existing languages. Rather, the influence of infants' learning biases during the repeated cultural transmission of the creole forces it to take on certain structures. Therefore, we need to understand what role fitness plays in the emergence of creoles in these models. We will then be able to compare the behaviour of the modified language dynamics equations with and (more realistically) without the fitness term.

The major difference is that the range of exposure probabilities at which a creole emerges is remarkably larger in the model without fitness than the one with fitness. When fitness does not play a role, the creole exists over the whole range of exposure probabilities. In contrast, in the model where fitness does play a role, there is a critical value for the exposure probability. Above this critical value, the creole is maintained in the population. Below it, the creole is eliminated. We conclude from these numerical analyses that fitness in fact acts to suppress the emergence of a creole when children are not significantly affected by other languages during the process of language acquisition.

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Emergent Compositionality in Language Evolution through Negotiation

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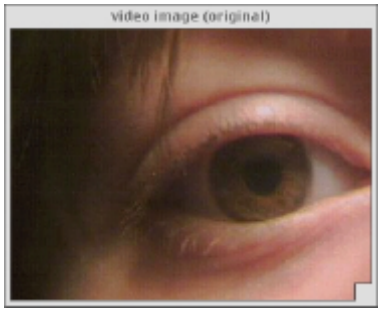
Compositionality is seen as one of the major properties of natural languages that any theory of language origins needs to explain. So far there have been quite a few computational experiments showing that compositionality emerges to handle the learning bottleneck. These experiments are usually framed in terms of the iterated learning model (Kirby & Hurford, 2001) where an agent is given a corpus and extracts a grammar which it then uses to produce a corpus for an agent of the next generation. In this paper we show that compositionality can also emerge in Language Game Models which rely on negotiation in peer-to-peer interactions and horizontal transmission (Steels, 2001). We also show that the choice for compositionality is based on properties of the environments. If there is regularity in the environment then there is an increased chance for compositional rules to dominate.

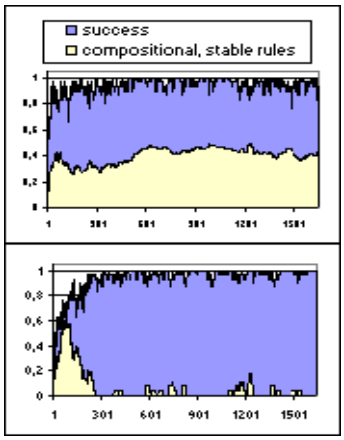
The experiment is similar to the Talking Heads experiment. The agents play a "Naming Game": They have to agree on a way to name an input they both see. The speaker may use one of its rules to map the input onto a word or create a new one. The hearer may understand this by a rule it already knows or induce a new one. If rules are used, their confidence scores are increased; competing rules that were not chosen are decreased. As the chance that a rule be used depends on its confidence score, this implements positive feedback and lateral inhibition mechanisms, driving a self-organisation process towards global coherence.

Inputs are three-dimensional vectors. Environments are probabilistic sets of input vectors. There are two kinds of environments: In the structured one, input vectors correspond to colours in digitized images, resulting in an extremely uneven distribution. In the unstructured one, vectors are created randomly with an even distribution.



Pictures used as structured input.

Compositionality comes into play as the agents may switch from rules expressing whole vectors to rules expressing only particular, reoccurring components.



Games in structured (top) and unstructured (bottom) environments.

In the experiment, we see that the population reaches a shared lexicon with high communicative success in both environments. Compositional rules, however, only stabilize in a structured environment. The stable compositional rules describe main axes among which input vectors vary - in the absence of such axes, no clear favourite can emerge and the holistic rules remain dominant.

While in the ILM, grammar is viewed as a system for the compact coding of meaning into form, in LGA, grammar is above all a way to optimise communication. In this context, finding that compositionality may arise without vertical transmission is not just a matter of style or focus, but supports profoundly different assumptions about how the origins of grammar can or should be approached.

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COGNITIVE AND FUNCTIONAL FACTORS IN THE EVOLUTION OF GRAMMAR

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The purpose of paper is to puzzle out different contributions of cognitive and functional factors in the origins and evolution of grammar. In brief, a factor will be said to be 'cognitive' if it is based on representations of meaning or thoughts. A factor will be said to be ''functional' if it is based on pressure for (more) efficient use of language among members of the species, particularly in communication. The conclusion is that cognitive factors are reflected in the genetically-transmitted aspect of grammars ('Universal Grammar'), while functional factors are primarily historical and have become more and more manifest with the passage of time.

The functionalist literature tends to stress the various ways that grammars seem 'designed' for communication. For example, one can argue that in significant numbers of cases, they accommodate themselves to the needs of parsing and/or discourse and they reflect frequency of use. Furthermore, as stressed in Hurford (2002), grammars contain many properties irrelevant to cognition (yet arguably aiding communication), among which are phonology, morphology, the conflation of semantic roles into grammatical relations, displacement operations, and so on.

Nevertheless, there are also many factors supporting an origin of grammar in cognition, which are enumerated in A-F below:

A. The importance of full argument structure.
B. The possibility of recursion.
C. The rampant structural ambiguity that grammars allow.
D. The possibility of communicatively absurd sentences.
E. The closer relation of grammatical categories to cognitive categories than to communicative ones.
F. The existence of covert levels of grammatical structure representing aspects of meaning.

I argue that these six design features of language pertain little -- if at all -- to communication and, furthermore, are not 'learnable' in the ordinary sense of the word. That fact suggests that they were there from the dawn of human language itself. Those aspects of language that seem designed to better aid communication, on the other hand, are historical, in the sense that we can see how they developed over time. I conclude by elaborating on a model outlined in Newmeyer (2003), in which human language grammar was originally based on primate conceptual representations, but became more 'communicatively adapted' with the passage of time.

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Developmental changes in the shape of the vocal tract in chimpanzees

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INTRODUCTION: The human larynx descends during postnatal life. The descent of the larynx forms a double resonator system with equally long horizontal (SVT_H) and vertical (SVT_V) parts of the supra–laryngeal vocal tract (SVT). This developmental phenomenon is believed to be unique to humans, contributing greatly to speech development by providing the necessary hardware. In this study, the postnatal developmental pattern of the SVT was examined in chimpanzees, using Magnetic Resonance Imaging (MRI). The results were compared with that reported in humans [1] to elucidate how and when the uniqueness observed in the adult human appears during growth.

SUBJECTS AND METHODS: Three living chimpanzee infants, named Ayumu (male), Cleo (female), and Pal (female) and fifty embalmed specimens, from perinatal to fully adult, were examined using a General Electric Signa Profile MRI scanner (0.2 Tesla) at KUPRI [2,3]. The living subjects were scanned at scheduled intervals from 4 months to 3.5 years of age, wherein they were anesthetized intra-muscularly and were placed supine with their heads fixed to the coil with belts. Care and use of the chimpanzees adhered to the guidelines of the KUPRI, and the protocol for the MRI examinations was approved by the Ethics Panel of the KUPRI. The proportional changes of the SVT were ascertained in the chimpanzees using the morphometric measurements on the MR images [2,3].

RESULTS: The laryngeal skeleton descended relative to the palatal plane in chimpanzees as in humans during growth, which was shown by increases of SVT_V length. However, the SVT_V length was shorter about 1.0 cm in chimpanzees than in humans. For living subjects, the laryngeal skeleton descended rapidly relative to the hyoid, but descent of the hyoid relative to the palatal plane was not accompanied in the first year of the age. After the second year, the hyoid also descended greatly in chimpanzees, as in humans, but the laryngeal skeleton descended slightly. The chimpanzee SVT_H increased gradually during early infancy as in humans, but its growth was accelerated to increase in chimpanzees faster than in humans. Thus, the ratio of the SVT_H to SVT_V lengths decreased by the end of the first years of the age, but after then it increased gradually toward the initial level. In contrast, in humans, it decreases during infancy and early juvenile toward 1.0 ratio.

DISCUSSION: These results showed that the descent of the larynx is installed not only in humans but also in chimpanzees. In early infancy, the descent is principally completed by the descent of the laryngeal skeleton relative to the hyoid, resulting in decrease of the ratio of the SVT_H to SVT_V lengths, but not accompanied with the hyoid descent relative to the palatal plane. After then, in chimpanzees, the horizontal oral cavity grows greatly to increase the ratio, although the larynx continues to descent relative to the palatal plane. This fact suggested that the double resonator system of SVT evolved at least in two steps, and not in a single step in the human lineage. The first step involved the descent of the larynx relative to the palatal plane at least in the common ancestor of chimpanzees and humans, maybe of the extant hominoids. The following steps in the human lineage involved loss of the development of the prognathism and increase of the vertical dimensions between the hyoid and palatal plane. The evolution was possibly effected principally by the structural modifications of the facial skeleton, not by the descent of the larynx. This two-step model should alter our perception of the evolution of the morphological foundation for speech.

ACKNOWLEDGEMENTS: This research was supported in part by Grants-in-aid for the 21st COE Research (Kyoto Univ., A14), JSPS-HOPE program, and Specially Promoted

Research (T. Matsuzawa, No. 12002009) from the MEXT of Japan.

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Mathematical Linguistics and Language Evolution

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Human languages exhibit a combination of computational features that make them unique systems of communication in nature: large and learned lexicons, combinatorial phonology, compositional semantics, and hierarchical phrase structure. In the field of evolution of language controversies have often focused on the complexity of these computational mechanisms. These controversies include debates about innateness, whether or not language was exapted, if it is the result of a few or many mutations and if it increased in complexity over evolutionary time (see e.g. Pinker & Bloom, 1990, and the many peer commentaries and the authors' response in the same issue). We analyze these debates and find that at their core they rely in varying degrees on two implicit assumptions: (i) that complexity in the computational machinery for processing language is difficult for evolution to achieve and/or that (ii) that complexity is itself a trait which can be selected for or against.

Out of the many possible ways of studying computational complexity, formal linguistics has primarily been concerned with situating natural language processes and formalisms on various computational hierarchies. By far the most studied of these is the (extended) Chomsky Hierarchy. We ask the questions: how do the two assumptions outlined above fare when analyzed under this notion of complexity, and how does this apply to the debates in the field? Such a formal definition would potentially resolve conflicting intuitions about complexity (exemplified e.g. in Lewontin's and Piatelli-Palmarini's commentaries on Pinker & Bloom, 1990).

We argue that complexity in the automata theoretic sense is in fact very common in natural systems. We find it plausible that genes can code for systems with small numbers of elements interacting with simple rules. There is increasing evidence that these sorts of systems are in fact often computationally universal (e.g. Wolfram, 2003). Furthermore, certain classes of neural network models have been shown to be Turing equivalent (Siegelmann & Sontag, 1991), and capable of efficiently encoding phenomena such as hierarchical phrase structure (Pollack 1988). We suspect that the reality is that brains in many kinds of animals are already implementing algorithms and computations which are sufficiently complex to represent and process language in the strict automata theoretic sense.

Furthermore, we go on to argue that these grammars and automata are not well suited to be used as phenotypes in biological models. They do, of course, expose interesting differences in grammatical classes on the hierarchy. For instance, the word recognition, or parsing problem increases in time complexity as one makes certain moves up the hierarchy. Likewise, differences in the hierarchy can be understood in terms of increasing relaxation of memory limitations, e.g. finite to stack based to stack based with less restrictive push procedures, etc. But it is difficult to see how these differences satisfy various evolutionary constraints or can affect fitness. We argue that instead of looking at these formalisms in terms of their place on the hierarchy we must look deeper at the properties of language that they are meant to abstract.

We summarise that it is not the physical constraints of the general

neural architecture that restrict natural language to a specific complexity class. Rather, the requirements of learnability and population coherence as well as the interface conditions of interpretability and producability under realistic time and noise constraints choose specific classes of computational mechanisms. These mechanisms restrict any language that is to survive either cultural or genetic transmission. We discuss the implications of this for the debates outlined in the introduction and reach some general conclusions. For instance, is it theoretically useful to describe the evolution of language as climbing the Chomsky hierarchy? (as do, e.g. Hashimoto & Ikegami, 1996). Finally, we conclude that while the Chomsky hierarchy is a bad model of phenotypic complexity, it is a very good model of language. This suggests a way of rescuing it as a tool for evolutionary theory.

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The self-organization of phonological patterns

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Human vocalizations have a complex organization. They are are digital and compositional: they are built through the combination of units, and these units are systematically re-used from one vocalization to the other. These units appear at multiple levels (e.g.the gestures, the coordination of gestures, the phonemes, the morphemes). While for example the articulatory space that defines the physically possible gestures is continuous, each language only uses a discrete set of gestures. While there is a wide diversity of the repertoires of these units in the world languages, there are also very strong regularities (for example, the high frequency of the 5 vowel system /e,i,o,a,u/). The way the units are combined is also very particular : 1) not all sequences of phonemes are allowed in a given language (this is its phonotactics), 2) the set of allowed phoneme combinations is organized into patterns. This organization into patterns means that for example, one can summarize the allowed phonemes of Japanes by the pattern "CV": a syllable must be composed of two slots, and in the first slot only the phonemes belonging to a group that we call "consonnant" are allowed, while in the second slot, only the phonemes belonging to the group that we call "vowels" are allowed.

It is then obvious to ask where this organization comes from. There are two complementary kinds of answers that must be given (Oudeyer, 2003). The first kind is a functional answer stating which is the function of systems of speech sounds, and then showing that systems having the organization that we described are efficient for achieving this function. This has for example been proposed by (Lindblom, 1992) who showed that digitality and statistical regularities can be predicted by searching for the most efficient vocalization systems. This kind of answer is necessary, but not sufficient : it does not say how evolution (genetic or cultural) might have found this optimal structure. In particular, naive darwinian search with random mutations (i.e. plain natural selection) might not be sufficient to explain the formation of this kind of complex structures : the search space is just too large (Ball, 2003). This is why there needs a second kind of answer stating how evolution might have found these structures. In particular, this amounts to show how self-organization might have constrained the search space and helped natural selection. This can be done by showing that a much simpler system spontaneously self-organizes into the more complex structure that we want to explain.

(Oudeyer, to appear) has shown how a system of this kind, based on the coupling of generic neural devices which were innately randomly wired and implanted in the head of artificial agents, could self-organize so that the agents develop a shared vocalization system with digitality, compositionality and statistical regularities. We present now an extension of this system which gives an account of the formation of phonotactics and of the formation of patterns in the allowed phoneme combinations. The extension is based on the addition of a map of neurons with temporal receptive fields. These are intially randomly pre-wired, and control the sequencial programming of vocalizations. They evolve with local adaptive synaptic dynamics.

The system provides a necessary complement to the functionalist explanation. Interestingly, it does not require the presence of a

functional pressure for efficient communication. It does not require any social pressure and agents have no social skills at all in fact. While modern speech codes are obviously influenced by the function of communication, the simplicity of the system allows to put forward a new hypothesis for the initial invention of shared organized vocalization systems: they might be a self-organized side effect of certain brain structures evolved for other functions than communication. We will develop this hypothesis by explaining which are these brain structures and what was their initial function.

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One leap or many steps: Can the Minimalist Program be reconciled with gradual evolution?

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"[T]he Minimalist Program...is...a research program concerned with...determining the answers to...the question "How 'perfect' is language?"" (Chomsky 1995:221)

The business of the language evolutionist is to provide theories which will constrain the set of possible models of language to those that point to plausible evolutionary origins of the faculty. Yet theories of language which are difficult to integrate into an evolutionary account nonetheless have been adopted by linguists without question. The Minimalist Program (MP) engenders such theories. This paper aims to address the question of the compatibility of the theory of language promoted by the MP with conceivable evolutionary processes giving rise to the capacity. The following issues will be considered:

- Does the minimalist notion of 'perfection' equate to the evolutionary notion of 'adaptation'?
- Are saltational stories the only possibility for evolution of a minimalist language faculty?
- Is the assumption of a MP for language methodologically sound?

The MP - the most recent incarnation of Chomskyan generative theory - is an attempt to reduce preceding approaches to a more elegant and parsimonious formalism. It aims to seek out and illustrate 'perfection' in the design of language, and eliminate the computational complexities previous generative theories of the system entailed. At first blush, this approach might seem to fit well with an adaptationist evolutionary story. However, deeper investigation establishes that this is not the position from which Chomsky's advocacy of minimalist ideas is derived. In fact, in moving from the complexity of Government and Binding theory, which assumed language to be underpinned by various interacting modules, to the simplicity of minimalism, the whole thrust of the Generative Enterprise has diverged from the adaptationist perspective.

By advancing an adaptationist story for language, the predictions we make are incongruous with the tenets of minimalism. Such predictions include: (1) adaptation must be the result (at least in large part) of natural selection; (2) natural selection must work in a gradual fashion; (3) a gradual evolution will be complicated by accidents of history; (4) gradual evolution by natural selection never finds the 'perfect' solution to a problem; merely the best one it can uncover given many conflicting constraints.

The language faculty as proposed in the MP does not resemble a system that has evolved in this way. The simplicity implied by reducing the computational system proves difficult to harmonise with our understanding of adaptationism. Berwick (1998) endeavours to overcome this difficulty by proposing a saltational explanation; simply introducing Merge into the evolutionary picture provides many of the unique features of human language. However, if this scenario were accurate, the language faculty would be anomalous in the biological world. Further, the 'perfection' that Chomsky discusses is fundamentally different to the optimality suggested by adaptationism. The latter will never reach the global maximum that the former implies.

The MP arose out of a wish to "...shift...to the...question: does the thing that we are studying have a certain kind of optimal character?" (Chomsky 2002:97). An adaptationist gradualist view, à la Pinker & Bloom (1990), follows Darwinian principles of reasoning in assuming language to be a complex biological system. Chomsky, following Galilean principles of reasoning, does not consider language from the biological angle, but begins from the methodological perspective of understanding how well 'designed' the system is. Ignoring the insights of biology can lead to miscalculated theories of language. The question that we therefore need to answer is whether seeking perfection in the computational system is the right way forward for linguistics.

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What has homo sapiens really bought at the cost of schizophrenia? Evolutionism seen through a philosophy of language

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One of the most intriguing positions in the evolution debate is that schizophrenia is the price that Homo sapiens pays for language. Language and schizophrenia are both unique traits of the human species and are equally distributed around the world. Crow (Crow, 1996, 2000) (Kim, 2000) proposed a common origin, back in a genetic mutation able to alter the anatomical and functional hemispheric balance, fixed in the sexual X chromosome about 100,000 years ago. Several facts support his thesis: the distribution of handedness among the normal and the psychotic population (Gur, 1977), the dating of the supralaryngeal vocal tract specialization (Lieberman, 1975, 1991), and the finding of FOXP2 as a putative genetic correlate (Enard et al., 2002). However, there are two drawbacks to Crow's theory, one concerning the evolution history and another the linguistic characterization of schizophrenia. On the first point, while schizophrenia and language are human specific, lateralization is not; on the contrary it is widespread among current species and through paleontological ages (Rogers and Andrew, 2002). Concerning the second point, the linguistic deficits connected to schizophrenia are highly arguable. If the schizophrenic patient were really deprived of the hemispheric specialized processes, his linguistic performances - especially syntax - should suffer as a result. This is not the case. Linguistic studies (Irigaray, 1985)(Pennisi, 1998), have shown that some schizophrenic patients even exhibit enhanced syntactic capabilities. They not only preserve normal articulatory performances but are especially able in morphological constructions (neologisms and paralogisms built on formally correct monemes) and discourse constructions (oral and verbal fluency, precise syntactic linkage and ordering). Thanks to such abilities, they can build complete "neolanguages". Extended linguistic analysis reveals that even verbigerations retain organization of meaning intact. So, what is the specific language pathology of schizophrenia? As Crow himself noted (Crow, 2000), the original traits of schizophrenia are a) internal voices; b) the theft of thought, and c) the escape of ideas. All seems to depend on a lost identification of the linguistic self. In other words, defects seem to seat at the upper cognitive level responsible for the self-identification mechanisms, showing, when corrupted by schizophrenia, a "loss of natural evidence" (Annett, 1999). Several EPR studies support this view (Rockstroh, 2001). Therefore the schizophrenic deficit seems to be a weakness in the ontological rooting of language in reality more than a defect in its formal mechanics. If this is the case, Crow's slogan can be rephrased as: "Schizophrenia is the price that Homo sapiens pays for the capability of language to generate existential semantics". And not for articulatory and syntactic capabilities. Still believing in a common root for language and schizophrenia, lateralization and the emergence of a linguistic consciousness now appear far too distant for an explanation. Too distant in time, from the origin of the brain hemispheric specialization to the evolution of a language-centered form of life. But too distant in ontogenesis as well, from the sole biological inheritance to the fundamental role of the cultural environment in the emergence of language functionality. Janet's "fonction du re? l" (Janet, 1903), can only emerge from the binding between the natural and the historical aspects of language, something which is missing from schizophrenic language.

Gestural signalling in bonobos (Pan paniscus), chimpanzees (Pan troglodytes) and gorillas (Gorilla gorilla): a comparison

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The primary goal of the present study was to enhance the knowledge and understanding of gestural communication concentrating on our closest living relatives, the apes. The present study is based on observations of Tomasello and colleagues [1994; 1997; 1985; 1989] on the gestural signalling of a group of captive chimpanzees (Pan troglodytes) and observations of two groups of gorillas (Gorilla gorilla) and two groups of bonobos (Pan paniscus) in captivity. Our goal was to compile the gestural repertoire of gorillas and bonobos and to focus on processes underlying social cognition, including learning mechanisms and the flexibility of gestural use, such as the adjustment to the attentional state of the recipient. The results enabled us to draw inter- and intra-species comparisons. The most intriguing differences between the three species become obvious concentrating on, 1) gestures in the sexual context, 2) the average number of gestures used, and 3) the variety of auditory gestures.

These differences seem to indicate general communication differences between the three ape species and are discussed in relation to their different ecological settings and social systems.

Keywords: gestures, learning, use, Pan paniscus, Pan troglodytes, Gorilla gorilla.

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Early symbolism: cognitive evidence for language abilities

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In the archaeological field of the reconstruction of language emergence, the majority of scholars agree that the combination of art, ritual burials, jewels, highly sophisticated tools and techniques occurring together demonstrate the existence of a fully modern language and a "symbolic" mind. One view is to posit that all these manifestations appeared lately and suddenly at the beginning of the Upper Palaeolithic some 50,000 years ago, during the so-called Cultural Explosion or Revolution (Klein 1999). According to this scenario, language and behavioural modernity would have emerged suddenly, tens of thousands of years after the emergence of our species Homo sapiens in East Africa. This model runs counter to the theory of a more gradual emergence of modern human behaviour and language (Appenzeller 1998), and debates abound about the existence of earlier manifestations of symbolism or technological development in Homo sapiens before the Cultural Revolution, or even in earlier hominids like Homo erectus or Homo neandertalensis. In addition to the scarcity of data, the main problem is of course that language and related behavioral abilities can only be deduced from indirect evidence, and that consequent possible misinterpretations of the data may lead to wrong conceptions about our ancestors.

At the beginning of Upper Paleolithic, modern humans were already dispersed over a significant area of the world. According to the Cultural Revolution hypothesis, the appearance of art, ritual burials etc. nevertheless took place in a very short scale of time, which is difficult to explain given the distances between human populations spread over tens of millions of square kilometers. Such notions as geographical distribution of early traces of symbolism and language have therefore to be taken into account in parallel to their ancestry to clearly assess the possibility of one scenario or the other. Our objective is to revisit a number of discoveries which can be considered as clues of an early modern behavior and language. In addition to the degree of confidence which can be attributed to their relevance, we analyze their spatiotemporal distribution to investigate whether it can be best explained by i) a unique and sudden emergence of language and symbolism, ii) a slower and more gradual process, or iii) several cradles of emergence which could be regarded altogether as a polygenesis of human cultural innovations.

Among the clues of modern behavior, the importance of pigments, and especially of red ochre, is pervasive all over Africa before the Upper Palaeolithic (Mithen, 1992, Dunbar et al., 1999), as examplified by the discovery of two 77,000 years old engraved pieces of ochre in the Blombos Cave (d'Errico & al. 2001), and is also attested in Australia (discovery of haematite pieces with ground facets and striations at the site named Malakunanja II) around 53,000 years ago (Roberts & al. 1994). The discovery of harpoons in South Africa more than 150,000 years ago, or the exploitation of maritime resources in Eritrea around 125,000 years ago (Walter & al. 2000) also imply a very ancient adaptation to the coastal environments. These bits of an early coastal culture can be further attested in the development of sea navigation (Coupé & Hombert 2002), which also took place before the Cultural Revolution attested in Europe or Near East. The question of early

burials in this region and more generally in Homo sapiens or earlier species (Carbonell & al 2003) will therefore be carefully discussed, in order to judge whether or not a scenario can be promoted which consider that modern behaviors and language emerged differentially at different periods in different groups of human beings.

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The Relative Role of Biological and Linguistic Adaptation in Language Evolution: A Computational Approach.

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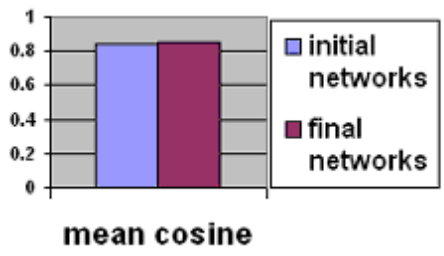
A crucial issue in understanding the evolution of language is to determine the relative contribution of linguistic and biological adaptation in the emergence of grammatical structure. A rapidly growing body of work focuses in the role of learning and cultural transmission in the evolution of linguistic communication, suggesting a key role for linguistic adaptation in the process of syntax emergence.

Using computational simulations, we here explore the hypothesis that linguistic rather that biological adaptation is the primary force in language evolution. We base our simulations on the assumption that when language emerged it would have had to "piggy-back" on pre-existing learning mechanisms (also suggested by Pinker & Bloom, 1990). Specifically, we focus on the role of pre-existing sequential learning mechanisms in language evolution, suggesting that early hominids evolved complex hierarchical learning mechanisms, which subsequently were utilized for the evolution of language. The question remains whether the process of subsequent language evolution would be characterized by biological or linguistic adaptation.

Our simulations involved generations of 9 differently initialized Simple Recurrent Networks (Elman, 1990). To simulate the emergence of hierarchical learning we first trained the networks on a complex sequential learning task. We allowed the networks to evolve "biologically" by choosing the best network in each generation, permuting its initial weights slightly to create 8 offspring, and then train this new generation on the sequential learning task. After 500 generations the error on sequential learning was reduced considerably, and we introduced language into the population. Thus, the networks were now trained on both sequential learning and language. Crucially, both networks and language were able to change, allowing us to pitch biological and linguistic adaptation against each other. At each generation, we selected the networks that performed best at language learning but only considering networks that maintained their earlier evolved ability for sequential learning (on the assumption that this type of learning would still be as important for survival as it was prior to language). At the same time, linguistic adaptation was implemented by selecting the best learned language as the basis for the next generation of languages. After another 500 generations, language learnability had improved considerably due to linguistic adaptation as indicated by a comparison of network performance on the initial and final languages (keeping networks constant; Fig. 1, right). Biological adaptation, on the other hand, produced very little change in performance, when comparing the initial generation networks with the networks from the last generation (keeping language constant, Fig. 1, left).

These results suggest that if languages and learners (networks) evolve simultaneously (while maintaining a pressure toward sequential learning), linguistic adaptation overpowers biological adaptation. This further highlights the important role of cultural transmission in the process of language evolution.



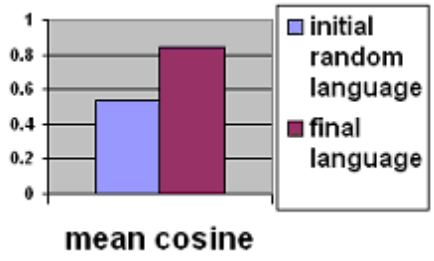


Fig 1: Right chart: language comparisons (networks constant). Left chart: network comparisons (languages constant).

The human tongue slows down to speak

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The tongue is the main organ of speech yet its biomechanics is poorly understood. Most vertebrate tongues have fast contracting muscles and the ATPase in their muscle fibers reflects this as all non-primate tongue muscles tested to date are composed entirely of fast twitch muscle fibers. In this study we examined the tongue muscles of neurologically normal adult humans (adults) for specializations as reflected by presence and distribution of slow twitch muscle fibers (StiMF), muscles fibers involved in fine gradations of force. In addition we used immunochemical methods to identify slow tonic muscle fibers (StoMF) a type of muscle fiber with unique biomechamical attributes that is extremely rare in mammalian muscles. As little is known regarding the functional significance of different types of muscle fibers in tongue muscles a variety of specimens were studied whose tongue activity in vivo differs from the adults (experimentals): early human developmental stages (newborn and 2-year-old infant); neurological disease (idiopathic Parkinson^Òs disease (IPD)); and comparative specimens (macaque monkey).

We found that adult human tongue muscles have a high percentage of StwiMF (54%). Among the experimentals the IPD patient (50%) as well as the 2 year old (54%) were similar to the adult whereas the human neonate and macaque had significantly fewer StiMF (31%). In both adults and experimentals the StiMF were distributed in a spatial gradient with few in the tongue blade and higher proportions posteriorly in the tongue base. The spatial gradient of StiMF is consistent with a postural role. The posterior tongue probably serves as stable platform for the more mobile tongue blade.

An extraordinarily high content of StoMF were found in adult tongue muscles (31%). In contrast to the gradient of StiMF the highest amounts of StoMF were in the blade (37%) and base (34%), with significantly less in the body (29%). Moreover, StoMF concentrated in muscles that shape the superior surface of the tongue, including newly described oblique muscles that were composed of nearly 90% StoMF. Among the experimentals both the IPD (24%) and neonate (16%) had significantly fewer StoMF then the adults (the 2 year old specimen was not tested). In contrast the macaque was remarkable for a relative lack of StoMF (estimated 5%).

The results suggest that tongue motor control is significantly higher in primates compared to other mammals, with adult humans having the greatest amount. In addition, the presence and distribution of StoMF in adult human tongues suggest it is related to speech, possibly the rapid changes in tongue shape that are uniquely seen during human speech. As similar specializations have recently been reported in the muscles of the human larynx and pharynx, but appear at comparatively low levels, if at all, in the same muscles of newborn humans or other mammals, it is proposed adult humans have a specialized motor control subsystem in upper airway muscles related to speech.

Overcoming semantic differences through mutual exclusivity

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In this paper, I describe computational experiments carried out on populations of simulated agents who develop their own communication systems based on inferring the reference of unfamiliar words from their presentation in multiple contexts. Communication is based on meaning inference in order to avoid the problems found in many computational models of language acquisition and development, which are characterised by the signal redundancy paradox: meanings are explicitly and accurately transferred between agents during communication, and therefore the signals which accompany them are redundant; yet if the signals are removed from the model, it is difficult to claim that the system represents a model of communication at all.

One of the most interesting puzzles of language acquisition, however, is how children learn the meanings of words so effortlessly, overcoming Quine (1960)'s problem of the indeterminacy of meaning with apparent ease. In order to explain this feat, many psycholinguistic biases have been proposed, such as the assumption of mutual exclusivity (Markman, 1989). Under this assumption, a child will ensure that a newly-encountered word does not refer to the same things as a word which already exists in their lexicon.

Computational models have recently been used to explore a world where agents create their own individual meanings following interactions with an external environment, and use context-driven disambiguation of the possible meanings to which a word refers (Smith, 2003). These experiments have shown that communicative success is very highly dependent on the level of conceptual structure which is shared by the agents. I build on these results here, by describing experiments in which the psycholinguistically plausible assumption of mutual exclusivity is incorporated into the existing model of successful communication.

On a semantic level, the introduction of mutual exclusivity into the hearer's interpretation process leads to the creation of new meanings in order to disambiguate the reference of unfamiliar words. Over time, this leads to the hearer developing relatively fewer meanings than in the experiments without mutual exclusivity, and different agents construct different conceptual structures. Despite this lack of shared meanings, however, the concepts created by the hearer are significantly more relevant and therefore more useful for communication than those in previous experiments. This results in relatively higher communicative success, as the assumption of mutual exclusivity allows the agents to overcome the differences in their conceptual structure.

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