

# Emergence and Evolution of Language

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I will try to picture the difficulty and controversiality of the problem of language evolution by a brief history. Then I will report some major opinions on the purpose of language and its evolution. One of the most ambiguous pieces of the language emergence puzzle is the emergence of trust in human societies. I will bring a discussion by Fitch on the evolutionary backgrounds which he believes sheds light on this dark piece. At the end I will explain a mathematical model to study language change based on a linguistic model which in continuous-time limit results in Fokker-Planck equation.

## I. INTRODUCTION

The study of origins and evolution of language has been one of the most controversial topics. It has not been accepted as a legitimate scientific problem for the majority of the scientific community till late twentieth century but many things have changed since then. Nowadays there are scientists who discuss the possibility of the problem being the hardest problem in science. There were already lots of debates on language origins going on when Darwin's *Origin of species* was published in 1959. Suddenly inspired by evolutionary paradigm in a very short period of time enormous number of conjectures were made which many of them could hardly lie in the scientific realm. The situation worsened to such a degree that the Linguistic Society of Paris which was considered the primary authority in the field banned discussions on the subject. This ban stopped scientific activity on the problem till 1975 when New York Academy of Sciences sponsors the conference *Origins and Evolution of Language and Speech*. Basically no scientific activity took place till the publication of the influential paper *National Language and Natural Selection* [1] by Steven Pinker and Paul Bloom. [2]

In the recent years the question has been attacked from different views and scientists from different fields exploited their tools and skills. Specially recent research in neuroscience and cognitive science can shed light on many aspects of the problem.

The subject was very broad, so I thought the best I could do was to concentrate on some basic fundamental debates. I will report the dominant opinions on language purpose in the first section. Then in the second part, I will go through the discussion on the evolutionary background that might have resulted in unique properties of language comparing to other communication forms used by other animals specially primates. Finally I will briefly explain about a mathematical framework for a linguistic model on language change.

## II. THE PURPOSE OF LANGUAGE

In spite of the numerous studies being done in the recent decades, there is still no considerable agreement on the answers to the questions like "What is the origin of language?",

“Why language was only developed in human beings not other apes for example?”, “What is the propose of language?”.

Regarding the last question there have been different suggestions. Influential people like Noam Chomsky [4] and Daniel Dennett [5] suggested thinking as the main purpose of language in mankind. A considerable number of the scientists active in the field specially the ones doing modeling and computational studies tend to accept communication and cooperation as the main motivation that resulted in emergence of language. The advantage of this approach is that one can use concepts, results or at least tools already developed in game theory models but there still remains this question that why other social animals could not develop language out of their primitive communication lines.

Though Chomsky considers language to be mainly developed for thinking in mankind, he doesn't deny its communicational application. He and colleagues [6] state that one has to distinguish the faculty of Language in the broad sense (FLB) with the faculty of language in the narrow sense (FLN). They discuss that the latter is more likely to have been developed for other reasons than communication and it includes recursion<sup>1</sup> which seems to be unique in human language and not present in any kind of communications used by other animals. They recommend comparative research so that we can find out if there is any levels of primitive recursion in other animals' communications and study the probable effective environmental factors. A few empirical studies have been done so far.

### III. TRUST, RELIABILITY AND KIN SELECTION

One of the most important characteristics of language that seems to be absent in any other animals' communications is *displaced reference*. It means through language human beings can refer to events which are far in space and time. This is where the concept of trust and reliability arises in studying language evolution. Most mammals produce vocal signals which are hard to fake. Vocal signals produced by primates seem to be more complicated and probably more manipulable, but still Machiavellian. It is very common to see a monkey or

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<sup>1</sup> Embedding phrases and propositions in other propositions to make complex syntactic structures.

an ape that deceives others to benefit more. So a monkey or an ape also guards against being deceived by neglecting the signals that are not immediately verifiable. Words do not fall into this category undoubtedly. Monkeys and other primates neglect whatever signals which are not about an event at here and now and that is why their communication never develops into a complicated structure similar to language. So one should be able of explaining the reason human beings started to trust each other. This is a very important fundamental question which need to be answered in any theory that tries to explain the evolutionary emergence of language in mankind.

In this regard, *kin selection* has been considered to play an important role in catering the conditions for emergence of language. W. Tecumseh Fitch explains [3] through comparative approach how kin selection can be in favor of emergence of honest propositions that carry meaning and information (semantic propositions). He discusses three main factors:

- 1) Long childhood period,
- 2) Extractive foraging techniques for humans and chimpanzees,
- 3) Male parental care which is only present in humans not in any other great apes.

Fitch explains how the low rate of reproduction in primates and long period of the infant's dependance on the mother results in solicitous primate mothers. The mother tends to share benefits with her offsprings who are unusually dependent on her for their survival. Long periods of foraging demands transferring complicated concepts and honest meaningful information to youngsters. Besides in human beings male parental care has been developed so males also are present in this communication network. These factors together do exist only in human kind so they should have had a very substantial influence in evolution of language.

#### IV. AN EXAMPLE OF A SIMPLE MATHEMATICAL MODEL FOR LANGUAGE CHANGE

A simple mathematical model of language change has been suggested by A. J. McKane and colleagues [7] which is very similar to Fisher-Wright model of population genetics. The mathematical model is based on the linguistic model by William Croft [8–10]. This article was interesting to me because except Croft the other three authors are physicists. This approach is fundamentally different from the evolutionary models considered for development of language capability which do need a very long period of time to take place. In this model language capability have been assumed and the emergence of various linguistic structures is being studied which can take place in a short period like tens of years. I will first introduce the model briefly, then I will go through the results.

There are  $N$  speakers and their utterances. The grammar relates a speaker to her utterance which she gains from hearing the variants and their frequencies. Variants are linguistic variables. There is a frequency corresponding to each variant showing how popular the variant is among a community of speakers. In Croft's model the evolution of language is studied through the change in the frequencies of these variants. The simplest possible language in this frame will include a single lingueme (a particular linguistic structure) with a finite number of variants  $V \geq 2$ . In this model the language change is being studied in three stages: Social Interaction, Reproduction and Retention. I will explain everyone briefly.

**1) Social Interaction:** At every time step two speakers  $i$  and  $j$  are picked randomly with probability  $G_{ij}$ , where  $G_{ij} = G_{ji}$ , and  $\sum_{\langle i,j \rangle} G_{ij} = 1$ . They communicate and the utterance being used influences both their and other speakers' grammars. Again for the next time step another two speakers are being selected and the process goes on. The grammar for every speaker is being defined as her knowledge of the frequency of different variants of the lingueme being used by the community, which is a function of time.

$$\sum_{v=1}^V x_{iv}(t) = 1, \quad \forall i, t. \quad (1)$$

where  $x_{iv}(t)$  stands for the frequency of variant  $v$  from speaker  $i$ 's point of view at time  $t$ .

**2) Reproduction:** Every speaker at every step is going to produce a combination of length  $T$  out of different variants. The probability of having sets  $\vec{x}'_i = (x'_{i1}, \dots, x'_{iV})$  and  $\vec{n}_i = (n_{i1}, \dots, n_{iV})$ , is

$$P(\vec{n}_i, \vec{x}'_i) = \binom{T}{n_{i1} \dots n_{iV}} (x'_{i1})^{n_{i1}} \dots (x'_{iV})^{n_{iV}} \quad (2)$$

, where  $n_{iv}$  stands for the number of variant  $v$  present in the combination of length  $T$ . It is obvious that  $\sum_{v=1}^V n_{iv} = T$ .

For an unbiased reproduction  $x'_{iv}(t) = x_{iw}(t)$ , because the speaker is reproducing what she is hearing, while for a biased one  $x'_{iv}(t) = \sum_w M_{vw} x_{iw}(t)$ .

**3) Retention:** The last step will be considering the changes that affected a member's grammar under interactions. At time  $t + \delta t$  the grammar of every speaker will be her grammar at time  $t$  being added to the contributions from her and the other members at time  $t$ . Different weights have been considered for her contribution and the other speakers'. Then the normalized grammar at the next time step would be:

$$\vec{x}_i(t + \delta t) = \frac{\vec{x}_i(t) + \frac{\lambda}{T} (\vec{n}_i(t) + H_{ij} \vec{n}_j(t))}{1 + \lambda(1 + H_{ij})}. \quad (3)$$

The authors do study their results through running the computer simulations of this discrete Markovian stochastic process and averaging over the large number of runs.

**Continuous-Time Limit:** The authors consider the continuous limit of this model in two cases. The first one is the single speaker case which is exactly soluble and has a correspondence in a population genetics model. The second case is where they find conditions that they have to imply on the model parameters to derive the general Fokker-Planck equation. The results are very similar to the case of one speaker.

$$\frac{\partial P(\vec{x}, t)}{\partial t} = \frac{\lambda^2}{2(1 + \lambda)^2} \sum_{v,w} \frac{\partial^2}{\partial x_v \partial x_w} (x_v \delta_{v,w} - x_v x_w) P(\vec{x}, t), \quad (4)$$

At this step, they compare the results of this model with the ones from Fisher-Wright [11, 12] model in both biased and unbiased cases. In this evolutionary model, linguemes play the role of genes in population genetics. So the fact that they both follow the same

mathematics is expectable.

They expect the social cases of formation of a new dialect to be the best empirical data for checking their results. They have started to analyze the New Zealand dialect using this model and the data they have.

Though they insist on non-triviality of single speaker model from mathematical point of view but this case is so very limited and I really doubt if it can help in understanding language changes as a social collective behavior. Besides the single lingueme condition is very limiting. Furthermore  $G_{ij}$  and  $H_{ij}$  are parameters that need to be derived from more realistic sociolinguistic models. But overall I think it is a very good start for attacking these types of problems from this perspective.

## V. CONCLUSIONS

The study of evolution and emergence of language is a very young interdisciplinary field full of mysterious facts. Numerous scenarios have been proposed but there still is no general agreement among the people who are active in the field. The complexity arises from the fact that as a collective behavior language has emerged to bridge the gap of communication in a group in which every individual has the capability of understanding and producing complicated concepts and structures. For evolutionary emergence of the language capability at present there are theories. Empirical data can be obtained from comparative research or archaeology evidence. Mathematical models and computational simulations are being helpful specially in studying short-term language changes, though we still are very far from even having a model which quantifies these changes.

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