A LITTLE BIT MORE, A LOT BETTER - LANGUAGE EMERGENCE FROM QUANTITATIVE TO QUALITATIVE CHANGE

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The draft of chimpanzee genome was published recently (Nature September 2005). It has been known that chimpanzees share more than 98% of our DNA and almost all of our genes. In addition to the striking genetic closeness, the studies on chimpanzees in both laboratories and natural habitats have revealed that they share with us many cognitive abilities (Tomasello & Call 1997; Hauser 2005), and exhibit complex social behaviors (de Waal 2005) and rich cultural traditions which are transmitted through social learning (Whiten 2005). In particular, chimpanzees have demonstrated cognitive abilities which are considered crucial for learning and using language, including manipulation of symbols, understanding of abstract concepts, intention reading and attention sharing, the ability of imitation, and so on.

While chimpanzees share a strikingly high degree of similarity with humans, the question about language origin become more intriguing: if chimpanzees are so close to humans in cognitive abilities and social behaviors, why can't they invent a complex communication system with compositionality, hierarchy, and recursion similar to humans?

Elman (2005) points out that "language sits at the crossroads of a number of small phenotypic changes in our species that interact uniquely to yield language as the outcome" (p114). It is these small phenotypic differences between human and chimpanzees that result in a communication means of a totally different nature. The study of complex nonlinear systems has shown abundant examples of such small quantitative differences leading to phase transitions, i.e.

qualitative differences, in the system dynamics. One classic example is the bifurcation observed in the logistic map (May 1976), in which the system changes from a stable end state to an oscillation end state, when the parameter changes from 2.999 to 3.001.

We use a computer agent-based model to show how the small changes of a few parameters of cognitive abilities would result in such a phase transition in the outcome of the communication system. The model simulates a group of agents interacting with each other with increasing communication ability. The agents possess a set of pre-linguistic abilities which have been shown to be shared by chimpanzees and humans, i.e. they have simple semantic distinctions between entity and action, and are able to sequence items, learn and use symbols, detect the interlocutor's intentions, and detect recurrent patterns (Gong et al 2005). The last three abilities are taken as parameters and varied as probabilities in the model.

The simulations show that when these parameters are all of low values, the group of agents can only develop a limited number of holistic signals. However, when these parameters cross some thresholds, a compositional language could emerge with a set of words and a certain dominant word order shared by the agents, which dramatically increases the communication efficacy of the group. The model thus suggests that even the chimpanzees share a great deal with humans, some small differences could divide the two species apart definitely.

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