

An Experiment Exploring Language Emergence: How to See the Invisible Hand and Why We Should

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The complex adaptive systems view of language sees linguistic structure arising via the interaction of three dynamical systems operating over different time-scales; *biological evolution* over the life-time of the species (phylogeny), *cultural evolution* of language itself over the life-time of the language (glossogeny), and *individual learning* (ontogeny) over the life-time of the individual (Kirby & Hurford, 2002). This approach sees these systems relating to one another in non-trivial ways, and the outcome being the cultural adaptation of language to the different constraints imposed upon it by transmission (Kirby, Smith & Cornish, 2007). These constraints can take a variety of forms, relating to cognitive limitations on processing and acquisition, or more functional/usage-based constraints existing at the population level. The effect is largely similar however; language adapts to become more easily learnable and transmittable by our brains rather than the other way around (Christiansen & Chater, 2007).

Previous work exploring these ideas has made extensive use of computational modelling and simulation (e.g. Kirby & Hurford, 2002; Brighton, Smith & Kirby, 2005). These models have shown that it *is* possible for language to evolve culturally in populations of artificial agents as predicted, and furthermore, that the resultant systems exhibit some key universal features of human language. This lends strong support to the idea that the mechanism of cultural transmission can play a very powerful role in the evolution of language. In spite of this however, very little is known about how such processes work in human populations, and there has been some scepticism as to the use of computational models being applied to this and other areas of language evolution (Bickerton, 2007). A simple question is therefore this: can the kinds of cultural adaptations seen in computational simulations be observed in human populations in the laboratory?

The development of experimental studies to explore aspects of language evolution is a fairly recent phenomenon. Previous work has explored the emergence of novel graphical communication systems in groups of experimental subjects (Fay et al., 2004), how pairs of subjects can converge on a shared symbol system whilst performing a cooperative task in an artificial world (Galuntucci, 2005), or even how subjects can navigate complicated signalling cost constraints to converge on an optimal shared system of communication (Selten & Warglien, 2007).

In spite of their many differences, one thing that all of these approaches have in common is the fact that they rely on their subjects consciously negotiating a system of communication. In other words, although the resultant systems show signs of cultural adaptation (i.e. the “appearance of design”), they are clearly constructed devices. To take the most recent study as an example, Selten & Warglien (2007) explicitly inform subjects that their task is to create a communication system with a partner, and that different symbols at their disposal in creating such a system have explicit costs which they should be minimizing. The language that emerged was therefore the product of careful design on the part of the subjects involved. Is this a good model for the emergence of linguistic structure?

Keller (1994) would argue not. As he sees it, much of what constitutes human language results from an “invisible hand” process – it is neither the result of intentional design, nor is it a natural kind. Whilst language change does have its origins in the actions of speakers, no single individual ‘decides’ to modify the language in order to effect an improvement. For instance, it is impossible to think of the transition from OV to VO in Old English as being an orchestrated manoeuvre. At the same time, this need not connote that all change effected in this way is simply random drift. It is a defining characteristic of an invisible hand process that the end result is adaptive, in the sense that it shows the appearance of design without a designer. Bearing this in mind, this paper asks a second question. We know from the previous experimental work already mentioned that cultural adaptation of language can come about through intentional acts, but can it also come about through the *unintentional* actions of individuals?

In order to address this, an alternative experimental framework is presented (Cornish, 2006) which confirms the central findings to have emerged from the computational literature: that language evolves to become learnable. The way in which this is achieved is by training subjects on a subset of an (initially unstructured) ‘alien’ language and then testing them. A sample of the output of generation n is then given as training input to generation $n+1$, and the process iterates. It will be shown that even when subjects are only exposed to half of the complete language during

training we still see gradual cumulative cultural adaptation leading to the emergence of an intergenerationally stable system, and that by changing the constraints on transmission (e.g. by favouring an expressive system over a highly learnable one) we see different types of structure emerge, such as compositionality. Furthermore, it will be shown that this can all be achieved without any intentional language construction on the part of the subjects.

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