# HYSTERESIS IN LANGUAGE EMERGENCE AND EVOLUTION

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Correlational studies have shown that the social structure can predict properties of language – first established for population size and morphological complexity (Lupyan & Dale 2010). In emerging sign languages, different social factors appear to result in different linguistic properties. For instance, Israeli Sign language (a Deaf community sign language) shows more conventionalization and less variability than Al Sayyid Bedouin Sign Language (an equally old shared sign language) (Meir et al. 2012). Several explanations have been proposed (and supported with computer models) based on, for instance, differences between adult and infant learning[1] (Dale & Lupyan 2012) memory limitations (Thompson, Raviv & Kirby 2020) or shared cultural knowledge (Mudd, de Vos & de Boer 2022).

None of these proposed explanations are mutually exclusive, and all of them may play a role in explaining the observed phenomena. However, they all provide a one-to-one mapping between the social property (e.g. group size or social network structure) and the linguistic property (e.g. morphological complexity or lexical variability). In other words, they propose that for any setting of the social property, there is *one* optimal value of the linguistic property. This abstract presents a first exploration of the consequences of abandoning this assumption, and an argument that this may help explain real linguistic phenomena.

The existence of multiple linguistic optima for some values of the social property creates the possibility of *hysteresis* (see left panel of Fig. 1). When the social property (for instance group size) increases for a particular population (in particular during language emergence) the (linguistic) property of its language stays stuck in the lower branch of the curve. When at a later stage the social property returns to an earlier value, the language may stay stuck on the upper branch, and thus appear quite different. This may explain differences between emergent languages and established languages with similar social properties.

[1] Dale & Lupyan's model focuses on morphology; the other models focus more on lexical variability.

A simple model of this phenomenon can be based on statistical physics: it is assumed that the distribution of the linguistic property (e.g. complexity of morphemes) follows a Maximum Entropy Distribution (MED). Properies of systems undergoing random fluctuations will tend to have MEDs. A MED can be characterized by setting its statistical moments to have fixed values[2]. In order to allow for hysteresis, the MED must have two peaks. A possible simple model constrains the mean of the distribution and the moment given by $\int dx \cdot p(x)(2x^2 - x^4)$. The precise shape of this second constraint is unimportant, only that it has two peaks, indicating that a language makes a compromise between two pressures. The distribution (with a scaling factor Z to ensure a total probability of 1) then becomes:

$$p(x) = e^{-\alpha x + \beta(2x^2 - x^4)}/Z \quad (1)$$

where $\alpha$ represents the social property, and $\beta$ determines how high the peaks are.

Simulating a varying value of the social property with a Markov Chain Monte Carlo approach (details in the supplementary material) shows hysteresis (right panel of Fig. 1). When the property increases, transition between the optimal states happens at a higher value than when it decreases. The transition is gradual: during the transition, the language is a mixture of the two linguistic optima.

This preliminary investigation shows that hysteresis can emerge from a simple model. The challenge is now to interpret the constraints on the moments in terms of cognitive and social factors and to define empirical tests to establish whether a model like this describes the linguistic reality accurately.

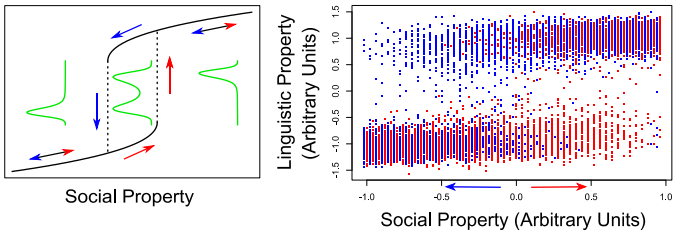


Figure 1. The left panel illustrates hysteresis qualitatively; solid black lines are trajectories of gradual change, dotted black lines jumps, and arrows indicate the direction of change. Green lines show the distribution of the linguistic property. The right panel shows hysteresis in a simulated language with 100 "morphemes" when a social property first slowly increases (red dots) and then decreases (blue dots). The transition does not occur in the same place when going up as when going down.


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[2] E.g. fixing the mean gives Boltzmann's distribution; fixing variance gives the normal distribution.

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