# ON THE ORIGIN OF UNIVERSAL CATEGORIZATION PATTERNS: AN *IN-SILICA* EXPERIMENT

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The Category Game is a computational model in which a population of individuals co-evolve their own system of symbols and meanings by playing elementary language games (Puglisi, Baronchelli, & Loreto, 2008). Consensus is reached through the emergence of a hierarchical category structure made of two distinct levels: a basic layer, responsible for fine discrimination of the environment, and a shared linguistic layer that groups together perceptions to guarantee communicative success. The only parameter of the model is the Just Noticeable Difference (JND) of the agents defined as the average detectable difference between two stimuli. Remarkably, the number of linguistic categories turns out to be finite and small, as observed in natural languages, even in the limit of a infinetesimally small JND. As in pioneering work on the coevolution of language and meaning (Steels & Belpaeme, 2005), finally, the shared categorization is reached through pure cultural negotiation, but in the Category Game the individuals, whose perceptual channel is for simplicity monodimensional, are additionally able to categorize a

continuum environment. The analogy with color categorization is therefore natural (Steels & Belpaeme, 2005; Puglisi et al., 2008), even though of course computational modeling implies a large number of (drastic) semplifications.

Here we focus on the (much debated (Lakoff, 1987)) question of the origins of universal categorization patterns across cultures. In particular, we report on an *in silica* experiment pointing out that cultural and linguistic interaction can induce universal patterns in categorization provided that human neurophysiology is taken into account (Baronchelli, Felici, Caglioti, Loreto, & Steels, 2006)[a]. We simulate, through the Category Game model, a certain number of non-interacting populations each one developing its own synthetic language. We find universal categorization patterns among populations whose individuals are endowed with the human JND function, describing the resolution power of the human eye to variations in the wavelength of the incident light (Long, Yang, & Purves, 2006). We furthemore show that, on the contrary, populations whose individuals' JND is uniform does no exhibit any signature of universality. In particular we repeat the same statistical analysis performed in (Kay & Regier, 2003) and we find that the difference between these two classes of simulated populations is in striking agreement with the difference between the experimental World Color Survey data and their randomized counterparts.

This is the first time, as far as we know, that a multi-agent model addressing the issue of categorization (i) incorporates a true feature of human neurophysiology (i.e. the human hue-JND), and produces results (ii) testable against and (iii) in agreement with experimental data. In addition, since the model was originally inspired by experiments employing embodied robots, and was designed to be as simple as possible, there is a particularly transparent connection between the hypothesis it incorporates and the results it generates.

## References


Baronchelli, A., Felici, M., Caglioti, E., Loreto, V., & Steels, L. (2006). Sharp transition towards shared vocabularies in multi-agent systems. *Journal of Statistical Mechanics*, *P06014*.

Kay, P., & Regier, T. (2003). Resolving the question of color naming universals. *Proc. Natl. Acad. Sci. USA*, *100*(15), 9085–9089.

Lakoff, G. (1987). *Women, fire, and dangerous things: What categories reveal about the mind.* Chicago: University of Chicago Press.

Long, F., Yang, Z., & Purves, D. (2006). Spectral statistics in natural scenes predict hue, saturation, and brightness. *Proc. Natl. Acad. Sci. USA*, *103*(15), 6013–6018.

Puglisi, A., Baronchelli, A., & Loreto, V. (2008). Cultural route to the emergence of linguistic categories. *Proc. Natl. Acad. Sci. USA*, *105*, 7936.


[a] fake citation, put for space estimation reasons only - it will become the arxiv of our wltb pnas.

Steels, L., & Belpaeme, T. (2005). Coordinating perceptually grounded categories through language: A case study for colour. *Behav. Brain Sci.*, *28*, 469.