Language, Perceptual Categories and their Interaction: Insights from Computational Modelling

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Introduction

How do humans acquire perceptual categories? This question is far from being resolved. Specifically the balance between the influence of nature and nurture on perceptual categories remains topic of heated debate. We present a computational model and take as case study colour categories to study two issues in perceptual category acquisition. The first issue is the effect of linguistic communication on categories during their acquisition. The second issue concerns the amount of coordination needed between the individuals' categories in order to achieve unambiguous communication.

Linguistic Relativism

The impact of language on cognition in its broadest sense is known as linguistic relativism or the Sapir-Worph hypotheses (Carrol, 1956). Brown and Lenneberg (1954) were among the first to suggest that language affects colour perception. These results interestingly contrast with the evidence for the universal character of colour categories. A statistical study of the data resulting from World Colour Survey confirmed that colour categories are indeed universal (Kay and Regier, 2003). This might suggest a strong genetic component at work. However, there are a number of alternative hypotheses which try to explain this universal nature (for a short survey see Kay and Regier, 2006). One is that culturally transmitted with its main vector being language. This latter hypothesis is at the basis of the computational models presented here.

Methodology

In order to investigate the influence of language on category acquisition, we have constructed two models. In model A, language has a direct influence on the category formation: both categories and their forms are learned simultaneously. In model B learning is divided into two stages: first the agents induce their categories individually from the environment and in the second stage they learn the forms for communicating about these categories without further changing their category repertoires.

The behaviour of the agents is implemented in terms of two simple scripts. The first script, the *discrimination game,* is defined at the of an individual agent and servers to let the agent develop a category repertoire sufficient for discriminating a single stimulus from the other stimuli in the context. The second script the *guessing game* is implemented at the population level. Its main goal is to develop a lexicon which is sufficiently shared in the population to allow for communication through language.

In the guessing game, two modes of interpreting a specific term are implemented. Using *lenient interpretation*, the agent chooses the stimulus which has the highest output for the category it associated with the given term. *Strict interpretation* additionally requires the category to be discriminative as well: no other stimulus in the context should be classified in the same category.

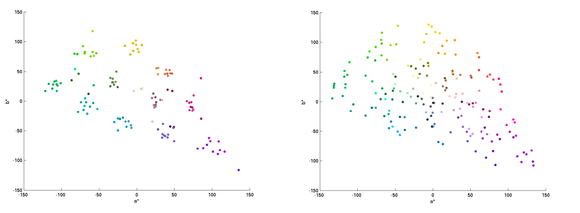

Figure 1: Resulting categories of all agents in the population at the end of a simulation for each model. When language has an influence on category acquisition (left), the categories tend to cluster. If agents acquire categories individually, without communication (right), the categories are spread out in perceptual space.

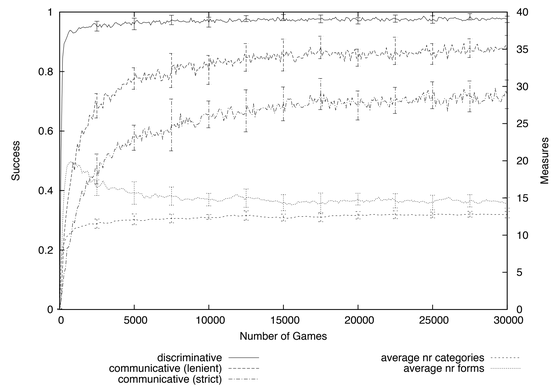

Figure 2: Results for model A (language influences category acquisition); results are averaged over 10 simulations.

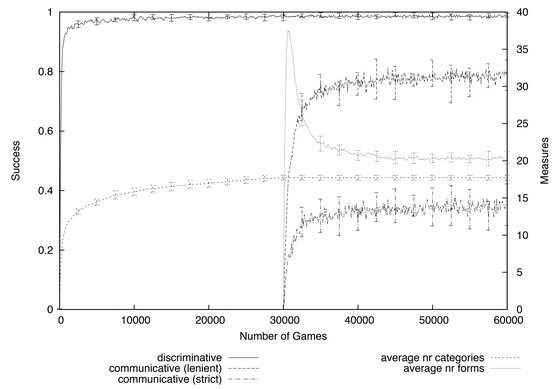

Figure 3: Results for model B (language does not influence category acquisition); results are averaged over 10 simulations.

Observations

The experiments confirm earlier results (Steels & Belpaeme, 2005): cultural acquisition of categories under the influence of language results in category repertories which are coordinated among all agents in a population. Figure 1 shows the prototypes of each category of all agents in a population at the end of one simulation. Model A results in categories which are clustered; model B results in colour categories which are scattered through the perceptual space.

Our model seems tolerant to the degree the categories are coordinated between agents (Fig. 2). Even if the agents are not at all coordinated, as is the case in the model where categories are acquired without the influence of language (Fig. 3), the agents still manage to acquire a term-category mapping which allows for good communication, provided that the interpretation of the hearer is not strict. However, if the hearer interprets a form by relating it to only one referent, communication breaks down if categories are not coordinated.

Conclusions

Our model suggests that perceptual categories can be rather different without hampering linguistic communication. The reason for this is that membership to a perceptual category decays gradually and continuously, making the mapping of a referent in the world onto a category tolerant to differences in individuals' categories. Webster and Kay (2005) seem to have observed this in colour categories, but our model suggests that this might be the case for any other type of categories with a continuous membership.

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