

Developmentally informed agent-based modeling of symbolic constraints in interaction

The relation of symbolic cognition to embodied and situated bodily dynamics remains one of the hardest problems in the contemporary cognitive sciences. It directly concerns the fundamental assumptions in theories of such basic cognitive processes as thinking and problem solving or using natural language. The stance one assumes towards this relation has consequences for basic research in these areas as well as applications in such fields as research of cognitive dysfunctions or designing artificial intelligent systems.

The present project aims at elaboration and verifying completeness and coherence of a one of the recent theories of the relation between symbol processing and situated action (Deacon, 1997; Rączaszek-Leonardi, Nomikou, Rohlfing & Deacon, 2018) by the means of agent-based computational modeling. This general theory of symbolic processing in cognitive systems has been proposed on the grounds of ecological psychology, dynamical systems and semiotics and concretized in the domain of natural language acquisition. The novel aspects of the theory are: i) treating informational structures as controls of interaction (rather than representations of the world) and ii) noting that symbolic forms of controls emerge from simpler forms, which are more obviously grounded in action in the environment and iii) basing the proposed mechanisms on data from studying language development processes.

The key sub-goals of the above main research aim will be: 1) to elaborate further the model on the theoretical level; 2) to test an array of modelling strategies and computational architectures for their suitability as models for the proposed processes; this step will crucially involve comparisons with the existing computational models of symbol emergence; 3) to test specific hypotheses of the theoretical model using the selected computational models: the tasks of the agents, the interaction possibilities, the properties of the communication media, and the information provided by the environment will be varied to test the consequences of the theory's assumptions and its explanatory power. Importantly, this step will be extended by 4) demonstrating the capabilities of the models with respect to the computational powers of the agent-based systems governed by the particular type of communication and control patterned on the novel approach to symbolic communication. Finally, 5) the above steps will culminate in posing a set of empirical hypotheses to be tested in later observational and experimental studies.

We will test the feasibility of the proposed solutions using the methodology of constructing agent-based communication models guided by actual data concerning the immersion of language in the ongoing interaction in development. We will use results from the newest literature in the field and from our own earlier studies; when needed, data will be supplemented by targeted analyses of the available corpora. The modeling strategies taken into account will be nature-inspired computational intelligence methods, such as

evolutionary computation, swarm intelligence and artificial life models. The agent's architectures which will be mostly based in universal recurrent neural networks architectures, supplemented when necessary with domain-specific components.

The project reflects the current trends in theory construction in the cognitive sciences in general and cognitive psychology in particular. In the face of the complexity of the investigated cognitive phenomena, i.e., the multilevel and multi-timescale nature of the structures and processes involved, researchers turn towards computational models as a preferred form of theory. The proposed computational models of symbolic communication emergence will i) contribute to the field by clarifying the assumptions and claims of the theory by constructing a working model and comparisons with other existing computational models, ii) test the theoretical hypotheses on the computational level and generate specific hypotheses for the subsequent experimental research in language acquisition domain and in joint-action paradigms in cognitive science. Last but not least, it will iii) assess the capabilities of the computational systems created on the basis of putative human symbolic communication processes from the point of view of their usefulness in artificial intelligent systems.