What are the challenges for Relational Science of Cognitive Systems?

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I will try to analyze the methodological challenges entailed by the relational context in which cognitive systems (whether biological, artificial, or a combination of both) are embedded. By “cognitive” systems, I mean systems that can perform functions such as perception, learning, memory, decision-making, problem-solving, language use, and reasoning.

Neuroscience (cognitive neuroscience included) is a relatively recent endeavor that evolved from and overshadows the traditional disciplines of neurophysiology and psychology. Neuroscience is conceived in the public eye, and unfortunately also in the eyes of many practicing scientists, as if there are no limits to its explanatory power. This situation should make us feel restless, because the hallmark of mature science is its ability to acknowledge its own limits, overcoming sentiments of omnipotence that characterize infantile stages of development. One may hope that future neuroscientific research will enable us to identify its boundaries, the limits of brain processes as valid explanations to behavior, expressing genuine acknowledgment and respect to the impacts of scale jumps. It would be very interesting to learn which behavioral phenomena reside outside the scope of the concrete topography of the network, at what level of structural organization the understanding of behavior becomes intellectually autonomous of its microscopic realization. Even further, what characterizes the larger class of systems that enable complex organism-like behavior – neurons being only one exemplar?

At present, too many neuroscientists delude themselves in believing that all that is required are measuring tools that allow one to look closer and closer, to find “the” machinery, “the” particle, “the” coordinates of complex behavior inside the brain; as if nothing resides outside, in the relational dynamics between entities, or between the cognitive system, objects and subjects in the environment. One reason for the adherence to such a naive course is its implementability within standard scientific paradigms. Stated differently, there is currently no known alternative, more appropriate conceptual framework to scientifically handle relational contexts. The study of structural–functional aspects of a given system under well-defined and largely static

environmental constraints is a natural extension of traditional paradigms in engineering and physical sciences. Within these paradigms we feel comfortable; we know how to optimize the design of experiments, how to perturb or displace the system and what to measure, how to build mathematical models of the system, and how to do the right statistics to optimize the models. From the very early stages of our science education, we are instructed to define control parameters, or independent variables, and how to carefully record order parameters or dependent variables that characterize the observed state of the system. Prevailing physiological and laboratory-based psychological inquiries implement this tradition by exercising maximal control on the presentation of stimuli. Indeed, when a stimulus – be it an object or a human subject – becomes unstable over the experimental session or (Heaven forbid!) sensitive to the state of the observed system, our observation is often deemed unsatisfactory.

But the dominance of relational contexts in evolutionary and ontogenic history of humans, where a 'state' *is* the relation between the system and the dynamic environment in which it is embedded, calls for reexamining this tradition. To uncover relational aspects of systems that are embedded in interactive environments – to expose the impacts of discontent, the resulting symmetry breaking, the entailed relational objects and their adaptive potential – new experimental concepts are called for. These should reflect acknowledgment that the individual cognitive system (actual brains, or artificial networks) is a cluster of 'cells', not much more; all the rest – all things that are psychologically meaningful – are out there, in the relations of the embodied cognitive system with the environment. The wanted experimental designs should allow the observed system to change its driving forces based on interactions with meaningful, dynamical, and responsive objects. This is not something that we know how to characterize. Unlike the traditional framework, there is no comprehensive theory that caters to measurements and their interpretations under such conditions. The inability to separate the system's dynamics from those of its environment stands at the basis of our limits in the study of cognitive systems and their relations to behavior. Vygotsky saw it, almost one hundred years ago. "The search for method[ology]" he said, "becomes one of the most important problems of the entire enterprise of understanding the uniquely human forms of psychological activity. In this case, the method is simultaneously prerequisite and product, the tool and the result of the study."

I will try to formulate preliminary steps toward wanted methodology.

Background Materials

(1) Marom S., (2020) D**ialogue Across Chasm: Are Psychology and Neurophysiology Incompatible?** *Neuron* 107 pp:600-602.

A general introduction for a wider readership to the methodological problem and the nature of wanted path.
https://drive.google.com/file/d/16CtrMNwxQgVBOf7KcZQgASqgLM2vt78K/view?usp=share_link

(2) Ori, H., Hazan, H., Marder, E. and Marom S.,(2020) **Dynamic clamp constructed phase diagram for the Hodgkin and Huxley model of excitability,** *PNAS* **117,** pp:3575–3582.

The potential of system identification using closed-loop control is demonstrated through an experimental-theoretical hybrid approach. This enables the identification of relationships between biological components and their expression in an abstract, low-dimensional representation of the system. The text is more technical, so those who are less familiar with the biophysics of membrane excitability might wish to read only the first two paragraphs of the Concluding Remarks section.
https://drive.google.com/file/d/1JHbm0CWuULIibTchHf_z7_X0TBWYv0Za/view