Generating Explanatory Hypotheses: Mind, Computer, Brain, and World

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Introduction

When puzzling events occur, people naturally generate hypotheses to explain them. This kind of thinking occurs in many domains, including:

- Science, where researchers generate theories to explain data;
- Medicine, where physicians generate diagnoses to explain patients' symptoms;
- Criminal investigation, where detectives form hypotheses to explain evidence from crime scenes;
- Machinery repair, where engineers diagnose mechanical faults to explain breakdowns;
- Social interaction, where people attribute emotions and other mental states to others in order to explain their behavior.

The purpose of the proposed symposium is to report and discuss new investigations of the cognitive processes that generate hypotheses, from a variety of disciplinary perspectives: artificial intelligence (Langley), philosophy (Magnani), cognitive psychology (Schunn), and computational neuroscience (Thagard). In order to provide integration across these approaches, we will try to address a fundamental set of questions, including:

1. How are hypotheses, explanations, and causality represented?
2. What triggers generation of explanatory hypotheses?
3. What are the mental and neural mechanisms by which explanatory hypotheses are constructed?
4. What are the socio-cognitive constraints on hypothesis formation?

The 4 speakers will also indicate the connections between hypothesis generation and other cognitive processes involved in problem solving and inference.

Participants

Pat Langley, Stanford University, USA

Computational Discovery of Explanatory Process Models

I will present an approach to computational discovery which encodes scientific models as sets of processes that incorporate differential equations, simulates these models' behavior over time, incorporates background knowledge to constrain model construction, and induces the models from time-series data. I illustrate this framework on data and models from Earth science and biology, two scientific fields in which explanatory process accounts occur frequently.

Lorenzo Magnani, University of Pavia, Italy

Reasoning through Doing: Epistemic Mediators in Explanatory Hypothesis Generation in Science

I maintain that the philosophical analysis of model-based and manipulative abduction and of the cognitive activity of external representations and epistemic mediators is important in understanding explanatory hypothesis generation in science. This talk will discuss how concrete manipulations of the external world constitute a fundamental passage in scientific discovery and explanation.

Christian Schunn, University of Pittsburgh, USA

Going from Blueberries to Liquid Water on Mars: How do Scientists Form Hypotheses When the Obvious Hypothesis is Not Politically Sanctioned?

Various pragmatic constraints play an important role in scientific hypothesis formation. One oft-discussed constraint is the scientist's personal attachment to previously developed theories. My talk will explore the cognitive abduction processes that JPL scientists used, as individuals and as a group, in resolving the institutional constraint in their hypothesis formation activities. The interesting comparison cases within this dataset are the constraints given by the researchers' own prior expectations and those voiced by other researchers on the project.

Paul Thagard, University of Waterloo, Canada

How does the Brain Form Hypotheses? Towards a Neurologically Realistic Computational Model of Explanation.

This talk will discuss explanation and hypothesis formation within the neurologically realistic computational framework used by Wagar and Thagard (*Psychological Review*, 2004) to investigate decision making. A neurocomputational model of hypothesis formation requires novel ways of representing hypotheses and explanations, as well as novel methods of manipulating neural networks to generate explanations. The proposed model employs neural representations of evidence that can be verbal or non-verbal (sight, sound, smell, taste, touch) as well as of emotional reactions to the evidence such as puzzlement.