Moot Point Process Models

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The Moot Point

Cognitive science aims to understand how humans and animals process information and to build models of these processes – often referred to as process models. However, there seems to be no consensus about what constitutes a process model or which process models are useful (see e.g., Pohl, 2011 for the Recognition Heuristic Model). This symposium will discuss the moot point process models from various perspectives. It brings together researchers who develop and work with different types of models, such as ACT-R, probabilistic computational models, quantum probability, or fMRI data. Focusing on models of judgment and decision making, they will present and discuss the level and scope of their models, which are all seen as candidates for a "process model".

Relevance

A discussion about this topic is timely: many formal models of human memory, attention, reasoning, or decision making carry the label "process model" and publications, which include the term process model, have been cited increasingly within the last decade even when controlling for a general positive citation trend (see Figure 1).

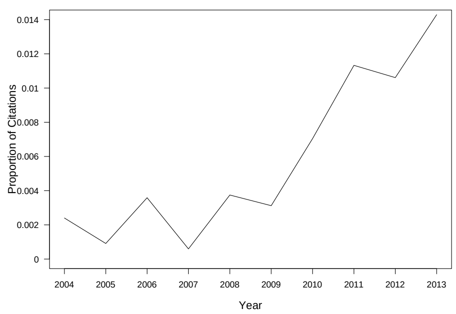

Figure 1 Increasing discussion of process models in cognitive science from 2004 to 2013. Number of citations of papers including the terms *process model* AND *(judgment and decision making OR decision making) AND psychology AND cognitive)* in relation to the number of citations of papers including only the terms *(judgment and decision making OR decision making) AND psychology AND cognitive).* Source: internet database Web of Knowledge.

If we asked what coins a process model in cognitive science, we might likely get multiple answers: A model that includes cognitive events unfolding over time (Townsend & Torii, 2005); one written in algorithmic and not analytic language (Gregg & Simon, 1967); one that predicts process data (Schulte-Mecklenbeck, Kühberger & Raynard, 2011); or a model which is intended to describe processes.

Aims

This symposium has four aims: First, the methodological debate about whether a process model or a different kind of model is "correct" is recurrent in the field. This debate centers mostly around the general relevance of investigating processes, how to model particular effects, and fitting vs. predicting specific data. Therefore, our first goal is to step back and try to understand what *kinds of process models* may exist for different classes of data and tasks. Second, some researchers argue that process models are superior to other models. The debate might remain circular if different experts disagree about the *features of the process model.* This needs to be resolved. Third, we want to find common dimensions of process models of attention, working memory, or decision making. By discussing them we hope to shed light on *similarities* of process models, such as a temporal order, and *constraints* between these models*,* such as working memory limitations. Fourth and foremost: an overview about different types of process models will hopefully set the stage for *theory integration through model integration*.

References

Gregg, L. W., & Simon, H. A. (1967). Process models and stochastic theories of simple concept formation. *Journal of Mathematical Psychology, 4,* 246-276.

Pohl, R. F. (2011). On the use of recognition in inferential decision making: An overview of the debate. *Judgment and Decision Making, 6,* 423–438.

Schulte-Mecklenbeck, M., Kühberger, A., & Raynard, R. (2011). The role of process data in the development and testing of process models of judgment and decision making. *Judgment and Decision Making, 6*, 733-739

Townsend, J. T., & Torii, K. (2005). Information processing. In L. Nade (Ed.), *Encyclopedia of Cognitive Science online,* John Wiley and Sons., doi:10.1002/0470018860.s00554.

Process Models as the Bridge Between Computation and Brain

Bradley C. Love

Theorizing in cognitive science occurs at multiple levels of analysis. For example, Marr proposed three levels of analysis:

implementation, algorithmic, and computational, roughly corresponding to the "where/what", "how", and "why" questions of cognitive science, respectively. Process models most closely ally with the algorithmic level's "how" questions. Lying between brain and computational levels of analysis, process models are ideally positioned to integrate findings at all three levels of analysis. For example, process models can be used to interpret brain imaging data and brain imaging data can be used to select among competing process models. Furthermore, process models can be aligned with rational computational accounts. Examples of this approach to integration are provided. The advantage of integration is that multiple data sources are leveraged to develop and constrain more complete theories of cognition.

Mack, M.L., Preston, A.R. & Love, B.C. (2013). Decoding the Brain's Algorithm for Categorization from its Neural Implementation. *Current Biology, 23,* 2023-2027.

Conceptualizing Process Model Characteristics

Jana Jarecki, Jolene Tan, & Mirjam Jenny

After the cognitive revolution we have witnessed a modeling revolution in cognitive science within which the term process model is used throughout judgment and decision making. Models based on decision field theory, Bayesian probabilistic models, algorithmic fast-and-frugal heuristics, and even models such as prospect theory, may carry the label process model. This talk reviews the properties of process models in the field, as they are used to describe and explain judgment and decision making in order to propose a unifying account of the term which is precise enough to be applied in the field. We will discuss a set of necessary components for a model to belong to the class of "platonic" process models which encompasses four building blocks of a process model. This allows for a comparison of existing models on these dimensions and can serve to guide future model building and amendment within the class of process models.

Where is the Process in Quantum Models of Cognition and Decision?

Jerome R. Busemeyer

Recently, a new theoretical framework for constructing models of human judgment and decision-making has been proposed based on mathematical principles derived from quantum probability theory. This new framework does not rely on the assumption that the brain is some kind of quantum computer. Quantum decision models have made impressive progress organizing and accounting for a wide range of perplexing findings in human judgment and decision-making using a common set of axiomatic principles. However, critics have argued that it lacks a foundation in cognitive principles and information processing mechanisms. This paper challenges this criticism by comparing the process assumptions of traditional cognitive versus new quantum models in two applications. The first application compares Markov (e.g., drift diffusion) versus quantum models of choice and decision time; the second application compares exemplar versus quantum models of category learning. We argue that quantum models are indeed processing models, but the processing mechanisms may seem new and unfamiliar to cognitive psychologists.

Busemeyer, J. R., Pothos, E. M., Franco, R., & Trueblood, J. S. (2011). A quantum theoretical explanation for probability judgment errors. *Psychological Review*, *118*, 193-218.

Pothos, E. M & Busemeyer, J. R. (2013). Can quantum probability provide a new direction for cognitive modeling?. *The Behavioral and Brain Sciences, 36,* 255-274.

Process Models of General Cognitive Skills

Niels A. Taatgen

Cognitive Science, and in particular builders of processing models, typically divide cognitive capacities into two categories: architectural or functional building blocks like working memory, attention, long-term memory and cognitive control on the one hand, and task-specific knowledge and strategies on the other hand. This is problematic, because it ignores a huge category of skills that are neither part of the architecture nor specific to a task. These general cognitive skills include but are not limited to heuristics for decision making, working memory strategies, strategies to reason about other people's knowledge, and strategies that involve cognitive control. The PRIM theory (Taatgen, 2013) is an extension to ACT-R that learns general strategies as a byproduct of learning task-specific skills, and is capable of explaining how these general strategies transfer between sometimes very different tasks. In my talk, I will outline the general theory, and show examples of process models in the area of cognitive control and decision making.

Taatgen, N.A. (2013). The nature and transfer of cognitive skills. *Psychological Review, 120*, 439-471.

Rational Process Models

Thomas L. Griffiths

Rational models of cognition are often presented as an alternative to process models, focusing on the abstract problem being solved and its ideal solution rather than the mechanistic cognitive processes involved. These two modeling approaches operate at different levels of analysis, making it hard to understand what claims rational models are making about cognitive processes and what implications cognitive processes might have for rational models. I will explore one way to develop a bridge between these levels of analysis, based on the idea of defining "rational process models" — models that explicitly have the goal of approximating the ideal solutions identified through rational analysis, but do so using components drawn from traditional psychological process models. This approach provides a way to gain new insight into the properties of existing process models (such as discovering that exemplar models can be used to approximate some kinds of Bayesian inference), and a strategy for deriving mechanistic hypotheses from rational models (such as the idea that human inferences might make use of the Monte Carlo principle).

Vul, E., Goodman, N.D., Tenenbaum, J.B., & Griffiths, T.L. (in press). One and done? Optimal decisions from very few samples. *Cognitive Science.*

Griffiths, T. L., Vul, E., & Sanborn, A. N. (2012). Bridging levels of analysis for probabilistic models of cognition. *Current Directions in Psychological Science, 21,* 263-268.