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BRAIN
BOOK REVIEW

Is there mathematics to madness?

It's hard to understand how heart failure can cause shortness of breath without some understanding of the role a pump plays in maintaining pressure gradients. The brain performs functions which are of a computational nature. Hence, a computational approach is likely necessary if we are to deeply understand disorders of brain function—particularly psychiatric disorders, where biological disturbances can be very subtle. More broadly, an understanding of the functions of an organ is critical if we are to comprehend the symptoms arising from disease in that organ.

Computational psychiatry is a young field that attempts to harness the advances in computational progress for improved understanding, prognosis and treatment of mental illness. It lies at the interface of psychiatry, experimental and clinical psychology, neuroscience, machine learning, artificial intelligence and computational neuroscience.[1] Computational psychiatry broadly encompasses two types of approaches. Data-driven approaches harness the advances in artificial intelligence, computational resources and big datasets. The theoretical branch, on the other hand, attempts to build mathematical or computational models of the relevant neural, circuit or cognitive processes.[2]

Novices to the field are often daunted by the need to gain some understanding of both mental health and formal methods. Typical teaching programs rarely allow for training in both, and at times may even exhibit some antagonism. Are equations really necessary to treat patients? Are mental health symptoms really a proper object for formal study? Recently, a number of exciting books and special issues have provided authoritative and helpful overviews of the field.[3,4] However, these are not introductory fare, and when contacted by students and researchers from across the globe asking how best to enter the field and acquire expertise in the various areas, I have often tended to point them towards a long list of books, one for each of the disciplines: some maths, some machine learning, some computational neuroscience, some reinforcement learning, some psychotherapy, some psychiatry, some neuroscience. It was a long list. And I think it put many promising young people off.

This new book is a very welcome remedy. The first few chapters contain broad introductory material, and these are then followed by chapters with more details on the current state of the art in our computational understanding of schizophrenia, depression, anxiety, addiction and tic disorders. The opening chapter emanates from the highest echelons of the US National Institute of Mental Health, being authored by Janine Simmons, Bruce Cuthbert, Joshua Gordon and Michele Ferrante. They provide a focused, impressively thoughtful and insightful overview over the recent history of psychiatry. The importance of computational methods is highlighted by the procession from Lapicque's integrate and fire model of neurons, Rall's cable theory, Hodgkin and Huxley's description of action potentials, Hebb's plasticity rules, and Barlow's

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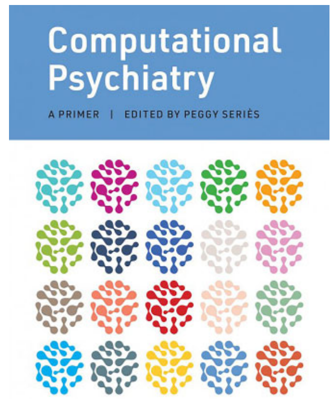

information theoretical characterization of sensory adaptation to today's models of reinforcement learning and neural networks. The second chapter, written by the overall editor Peggy Seriès, provides what might end up being the most useful and important chapter for students: a whistle-stop tour through the main theoretical approaches, elegantly identifying the key formalisms and outlining their applications.

The next three chapters provide in-depth reviews of biophysically-based neural network models, cognitive control and reinforcement learning as applied to issues in mental health. All of these should be highly recommended reading, both for seasoned practitioners in the field and novices, as they clearly identify and describe both conceptually and formally the key ideas and their applications. Xiao-Jing Wang and John Murray describe how dynamical models enable cellular-level processes to be related formally and clearly to high-level phenomena, for instance how alterations in receptor dynamics affect working memory. Peter Dayan deploys his writing prowess to delightful effect, comfortably guiding us through the vast territory of reinforcement learning at breakneck speed. It's not all about prediction errors, but rather about how one can turn the patchwork of biologically relevant rewards into a coherent strategy for happy survival. Debbie Yee and Todd Braver, finally, summarize the work on cognitive control, starting from early connectionism and taking us through to recent advanced statistical models.

The second half of the book is dedicated to chapters on specific diseases. The tone now changes. There is much more emphasis on the clinical picture and this is, maybe by necessity, much more shaped by established views of the disorders. Rick Adams leads the charge, separating out computational accounts of positive, negative and cognitive symptoms in schizophrenia before walking us through an example of attractor dynamics in belief updating.

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Samuel Rupprechter, Vincent Valton and Peggy Seriès follow with a description of depression. Their discussion is organized in terms of models rather than clinical symptoms—spanning the gamut from connectionist to drift diffusion, reinforcement learning and Bayesian decision theory models. Next, Erdem Pulcu and Michael Browning hold our hand while they walk us through the volatile landscapes of anxiety. David Redish then covers economic, pharmacological and learning models of addiction, concluding that there is strong evidence for runaway valuations in response to drug use. Societally, he emphasizes, this may mean we need to focus on drug use, not drug addiction. An important point he makes particularly clearly is how failures in multiple components contribute to addiction.

The most substantial chapter is devoted to Tourette's syndrome. After reviewing the existing literature, Vasco Conceição and Tiago Maia outline an integrative, theory-driven account of Gilles de la Tourette's syndrome around the key argument of a dopaminergic hyperinnervation. The selection of disorders to focus on may seem eclectic to clinicians but reflects the areas where most work has been done.

As should be clear from the description, the book has many strengths, and much to like. It should become a useful and approachable, hence important, introductory text to those interested in the field. The most glaring and significant omission is that of data-driven or machine-learning approaches.[5] In my view, this is a missed opportunity, and hopefully this will be addressed in future editions. The second striking limitation of the book reflects the current state of the field: half computational neuroscience, half clinical science. Both the book and its constituent chapters continue to reflect either standard clinical or theoretical boundaries, and their proper integration remains outstanding. It might be that this picture persists until computational methods start influencing and shaping clinical practice.[6] The road until that becomes reality may be long. But as an accomplished cyclist, Peggy Seriès delights in long rides. Here, she and her co-authors have laid an excellent platform on which to form a peloton to help us travel faster.

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