Book Review: *Cerebral Cortex: Principles of Operation*

By: Edmund T. Rolls
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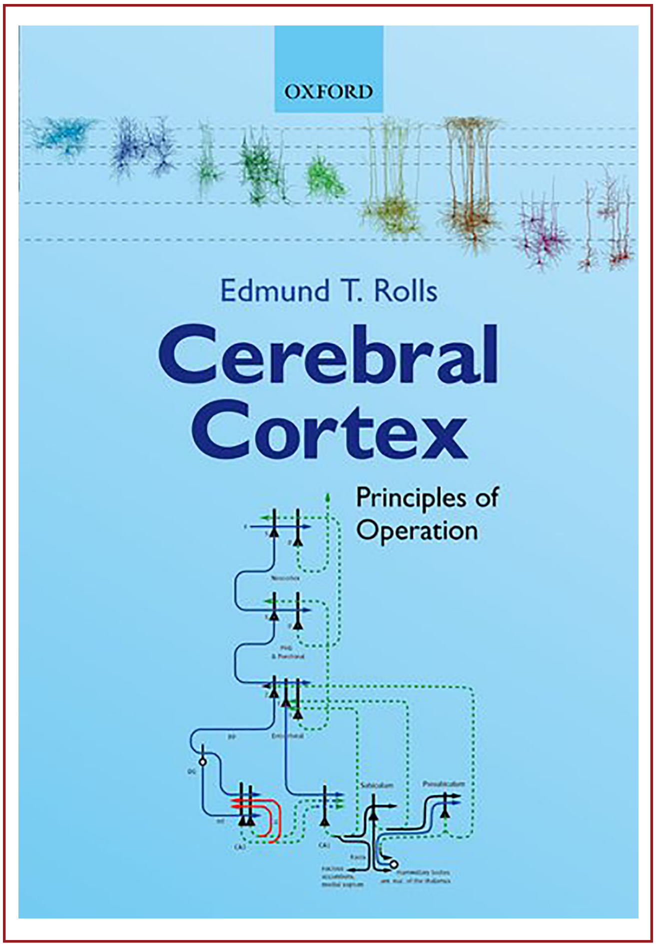
Simulating the function of the human brain is the ultimate dream of any neuroscientist, and decades of work have taken us from single-neuron spiking models to simulations involving large populations of neurons to produce collective behavior.[1–3] Meanwhile, advances in high-performance computing have made feasible such large scale computations on commodity hardware.[4]

The author Edmund Rolls directs the Oxford Centre for Computational Neuroscience (Oxford, United Kingdom) and is a professor of Computer Science at the University of Warwick (Coventry, United Kingdom). He has been prolific with regard to connecting low-level computational models and high-level human behavior such as decision making and emotion. *Cerebral Cortex* weaves together many of the themes found among his papers and provides a comprehensive and unified text.

It is immediately clear that *Cerebral Cortex* is a thorough review. Flipping through, the pages are dense with text, formulas, diagrams, and experimental data, yet it reads clearly and is well organized. Its goal is to provide both theory and experimental evidence to guide our understanding of the operation of the cerebral cortex, and it will be of interest to any neuroscientist working to understand, model, and simulate the mechanics of cognition.

While many textbooks on the topic spend chapters on the basics of single spiking neurons, the author moves quickly to systems-level network analysis guided by neurobiology. Instead of getting mired in the details of individual spike data, the focus is on network topology and balancing feedback. Because of its breadth and depth, the text is well suited for a graduate level course in neuroscience.

The book starts with a quick but thorough introduction to the properties of individual neurons and network effects while introducing dynamics to model long-term potentiation and depression. All the while, Professor Rolls integrates decades of theoretical and experimental work in neurophysiology. The bulk of the introduction is spent laying out a systems view of brain function derived from neurobiology, revealing the specific connections we seek to model. The intuition is that the brain is not simply a glob of homogenous neurons in connection but is instead composed of highly specialized subsystems, each with unique but recurrent architecture. For example, the visual system able to determine not only what an object is but also its location, the hippocampus with its episodic properties, or the frontal lobe with attention, working memory, and planning. Professor Rolls



reviews fascinating experimental work to elucidate many of these hierarchical subsystems.

The text describes attractor networks, neuronal configurations with excitatory interconnections that can settle into a stable firing pattern. Such topologies can encode memory in the hippocampus as well as perform decision making and planning. In fact, the same fundamental architecture can model short-term memory, episodic memory, semantic memory, and decision-making. The author draws on experimental evidence for such network implementations in the hippocampus and neocortex as well as exploring their properties of speed, storage capacity, and learning.

With any physical system, noise must be accounted for, and Professor Rolls has an excellent treatment of stochastic effects with regard to decisions and memory, complete with a review of simulations and experimental data in addition to results from functional magnetic resonance imaging. The text follows this noise from the level of individual neuron all the way up to high-level behavior. Noise, it argues, is key to much of our psychology and perturbations can contribute to psychiatric disorders.

Visual attention is covered in detail including top-down bias from memory as well as bottom-up competition from visual stream processing. Care is taken to integrate the underlying microscopic neurodynamic mechanisms. The proposed model argues that there is not some mysterious controller of attention but that much of attention is directed from memory biasing visual processing, as evidenced by activation patterns produced from neuroimaging. Other key chapters examine neurogenesis and aging, psychiatric disorders, language, the cerebellum, and more.

In such a dense book, a key feature is concise highlights at the end of each chapter. Not simply a set of bullet points to gloss over, I found myself carefully studying these. Another welcomed aspect of this book is the frequent connections the author makes between chapters to reinforce concepts, clarify important points, and provide complimentary explanations. The final chapter was essentially a birds eye view of all preceding chapters highlighting recurrent themes and integrating systems to give an organized view of cortical operation.

With all the buzz surrounding "deep learning", Professor Rolls takes care to contrast generic top-down computational models vs those grounded in biologically plausible models scaled up to produce function. The former is often labeled a "connectionist" approach. The text briefly discusses deep learning and other popular implementations but is quick to downplay these as biologically implausible and thus not as useful to understanding true cognition.

While the text integrates experimental data, the focus of the book is more on proposing theoretical models and often refers out to experimental support. As such, this book is better suited for those interested in the theory spanning low-level models and high-level behavior, rather than a text with simulation results. While the references were extensive, few were from the last 5 to 10 yr, a period that has seen explosive growth driven by computational advances. While no text is complete, those interested would do well to pair this with computational readings.[3]

Coming in at just under a thousand pages including references and appendices, this book is packed with hundreds of figures illustrating proposed networks or presenting published experimental results. All figures are of the highest quality with many in color to distinguish details. The book's website includes example MATLAB software (MathWorks, Natick, Massachusetts) for simulating 3 basic neuronal configurations. The code is clear and well documented, and I was able to execute the simulations without issue.

Overall, I recommend this book to the neuroscience community for its thorough review and proposed models. It is a comprehensive yet accessible text for anyone seeking to understand the deep mechanics of how we think. I commend Professor Rolls for this and his other excellent contributions to the field.

Disclosure

The author has no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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