



## Biological Learning and Control: How the Brain Builds Representations, Predicts Events, and Makes Decisions (Computational Neuroscience Series)

By Reza Shadmehr, Sandro Mussa-Ivaldi

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In *Biological Learning and Control*, Reza Shadmehr and Sandro Mussa-Ivaldi present a theoretical framework for understanding the regularity of the brain's perceptions, its reactions to sensory stimuli, and its control of movements. They offer an account of perception as the combination of prediction and observation: the brain builds internal models that describe what should happen and then combines this prediction with reports from the sensory system to form a belief. Considering the brain's control of movements, and variations despite biomechanical similarities among old and young, healthy and unhealthy, and humans and other animals, Shadmehr and Mussa-Ivaldi review evidence suggesting that motor commands reflect an economic decision made by our brain weighing reward and effort. This evidence also suggests that the brain prefers to receive a reward sooner than later, devaluing or discounting reward with the passage of time; then as the value of the expected reward changes in the brain with the passing of time (because of development, disease, or evolution), the shape of our movements will also change. The internal models formed by the brain provide the brain with an essential survival skill: the ability to predict based on past observations. The formal concepts presented by Shadmehr and Mussa-Ivaldi offer a way to describe how representations are formed, what structure they have, and how the theoretical concepts can be tested.

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## **Editorial Review**

### Review

An introductory examination of the book reveals many pages of somewhat daunting, complex mathematics; however, the text explains the mathematical applications thoroughly and, often, delightfully...Like the clever examples provided throughout this book, the insights into brain function provided by Shadmehr and Mussa-Ivaldi have broad applications. I believe this book would be a great choice for an undergraduate special topics course; it just might inspire greater interest in the biomedical applications of mathematics. **Peggy L Edds Walton** *BioScience*

This exciting book provides a coherent framework for understanding how the brain learns to control the body. By synthesizing recent advances with historical perspectives, it provides an accessible entry point for both biological and engineering students, as well as a valuable resource for professionals seeking to understand the workings of the brain.

(Daniel Wolpert, University of Cambridge)

As neuroscience moves into the 21st century, insights from theories, neurobiological and behavioral experiments are molded into an understanding of the nature of perception, action and cognition. The authors guide the reader through data and theory, revealing deep and beautiful insights into the way uncertainty and environmental constraints shape the way we move and learn.

(Konrad Körding, Associate Professor, Northwestern University; Lead Scientist, Rehabilitation Institute of Chicago, Center for Parkinson's Disease)

Almost 20 years have passed since Reza Shadmehr and Sandro Mussa-Ivaldi published their seminal work on motor adaptation, leading to an explosion of research on how we learn, retain, and generalize our movement skills. This book brings these studies together into a unified and coherent theory of adaptive motor control, synthesizing recent ideas on space perception, state estimation, reward maximization, optimal control, and many other fascinating topics. The result is sure to become an influential milestone in the field, leaving one eager to see what the next 20 years will bring.

(Paul Cisek, Department of Physiology, University of Montréal)

### About the Author

Reza Shadmehr is Professor of Biomedical Engineering and Neuroscience at Johns Hopkins University and the author of *The Computational Neurobiology of Reaching and Pointing* (MIT Press, 2005). Sandro Mussa-Ivaldi is Professor of Physiology in the Medical School at Northwestern University, with joint appointments in Physical Medicine and Rehabilitation and Biomedical Engineering. He is also Founder and Director of the Robotics Laboratory at the Rehabilitation Institute of Chicago.

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#### **Kathleen Owen:**

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