Title
Dynamic Field Theory: Conceptual Foundations and Applications in the Cognitive and Developmental Sciences

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 30(30)

ISSN
1069-7977

Authors
Spencer, John P.
Schoner, Gregor

Publication Date
2008

Peer reviewed

Dynamic Field Theory: Conceptual Foundations and Applications in the Cognitive and Developmental Sciences

John P. Spencer (john-spencer@uiowa.edu)
Iowa Center for Developmental and Learning Sciences
Department of Psychology, E11 Seashore Hall, University of Iowa
Iowa City, IA 52242 USA

Gregor Schöner (gregor.schoener@neuroinformatik.ruhr-uni-bochum.de)
Institut für Neuroinformatik, Ruhr-Universität Bochum
44780 Bochum, Germany

Abstract

Dynamical Systems Theory has had a major impact on how researchers think about sensori-motor behavior. Recently, Dynamic Field Theory (DFT) has provided a critical bridge from motor control and development into cognitive function. One obstacle for researchers wishing to use DFT has been the mathematical and technical skills required to make these ideas operational. The DFT Tutorial will provide the tools needed to overcome this hurdle.

Keywords: Neural networks; cognitive neuroscience; embodied cognition; cognitive development.

Tutorial Overview

The concepts of Dynamical Systems Theory have impacted the way psychologists, cognitive scientists, and neuroscientists think about sensori-motor behavior and embodied cognition. These concepts have had a particularly strong impact in developmental science, changing the way questions are asked, experiments are designed, and theoretical models are formulated.

A critical step for Dynamical Systems thinking has been the move from its initial setting in motor behavior into cognitive function. This move was prefaced by extensive discussion within Cognitive Science about whether Dynamical Systems accounts must embrace the concept of representation. Dynamic Field Theory (DFT) provides an answer to this question, offering a framework for thinking about representation-in-the-moment that is firmly grounded in both Dynamical Systems thinking and neurophysiology.

Dynamic Neural Fields are formalizations of how neural populations represent the continuous dimensions that characterize perceptual features, movements, and cognitive decisions. Neural fields evolve dynamically under the influence of sensory inputs as well as strong neural interaction, generating elementary forms of cognition through dynamical instabilities. The concepts of DFT establish links between brain and behavior, helping to define experimental paradigms in which behavioral signatures of specific neural mechanisms can be observed. These paradigms can be modelled with Dynamic Neural Fields, deriving testable predictions and providing quantitative accounts of behavior.

One obstacle for researchers wishing to use DFT has been the mathematical and technical skills required to make the ideas operational. The goal of this tutorial is to provide the tools needed to overcome this hurdle. We will provide an overview of the central concepts of DFT and their grounding in both Dynamical Systems concepts and neurophysiology. Next, we will discuss the concrete implementation of these concepts in Dynamic Neural Field models and provide the group with some hands-on experience using real-time simulators in Matlab. Finally, we will give an overview of how the basic concepts and models have been extended to account for cognitive and developmental phenomena and discuss how this provides a formal framework for thinking about embodied cognition and the integration of processes across multiple time scales.

Tutorial Leaders

Dr. John P. Spencer
Associate Professor, Department of Psychology, University of Iowa
Co-Director, Iowa Center for Developmental and Learning Sciences

John P. Spencer is an Associate Professor of Psychology at The University of Iowa and the founding Co-Director of the Iowa Center for Developmental and Learning Sciences. He received a Sc.B. with Honors from Brown University in 1991 and a Ph.D. in Experimental Psychology from Indiana University in 1998. He is the recipient of the Irving J. Saltzman and the J.R. Kantor Graduate Awards from Indiana University, as well as the Early Research Contributions Award from the Society for Research in Child Development and the Robert L. Fantz Memorial Award from the American Psychological Foundation. His research examines the development of visuo-spatial cognition, spatial language, working memory, and attention, with an emphasis on dynamical systems and neural network models of cognition and action. He has had continuous funding from the National Institutes of Health and the National Science Foundation since 2001.

Professor Dr. Gregor Schöner
Professor of Neuroinformatics
Chair for Theoretical Biology, Institut für Neuroinformatik, Ruhr-Universität Bochum, Germany

Gregor Schöner is a Professor of Neuroinformatics and the Chair for Theoretical Biology at the Institut für Neuroinformatik at the Ruhr-Universität Bochum, Germany. He received his PhD in 1985 in theoretical physics at the University of Stuttgart under the supervision of Hermann Haken, the founder of the field of synergetics. After several years as a Visiting Scientist and Research Associate at the University of Connecticut and the Center for Complex Systems at Florida Atlantic University, Dr. Schöner became a Group Leader at the Institut für Neuroinformatik. In 1994, he became a director of Research at the CNRS in Marseille, France, returning to Bochum, Germany in 2001 to accept the Chair for Theoretical Biology. Dr. Schöner has numerous grants from different agencies in Germany, France, and the European Union. He's published over 60 refereed journal articles, including several that have appeared recently in Psychological Review and Behavioral and Brain Sciences. Dr. Schöner is considered one of the world's experts on dynamic systems theory within the fields of Psychology and Cognitive Science, and he is a pioneer in the application of Dynamic Neural Fields to the study of cognition and autonomous behavior.

Suggested Readings

Johnson, J.S., Spencer, J.P., & Schöner, G. (2007). Moving to higher ground: The dynamic field theory and the dynamics of visual cognition. In F. Garzón, A. Laakso & T. Gomila (Eds.), Dynamics and Psychology [special issue]. *New Ideas in Psychology*, doi:10.1016/j.newideaspsych.2007.07.007.

Schöner, G. (in press). Development as Change of System Dynamics: Stability, Instability, and Emergence. In Spencer, J.P., Thomas, M.S., & McClelland, J.L. (Eds.) *Toward a New Grand Theory of Development? Connectionism and Dynamic Systems Theory Re-Considered*. New York: Oxford University Press.

Simmering, V.R., Schutte, A.R., & Spencer, J.P. (2008). Generalizing the dynamic field theory of spatial working memory across real and developmental time scales. In S. Becker (Ed.) *Computational Cognitive Neuroscience [special issue]. Brain Research, 1202*, 68-86.

Spencer, J.P. & Schöner, G. (2003). Bridging the representational gap in the dynamic systems approach to development. *Developmental Science, 6*, 392-412.

Spencer, J.P., Simmering, V.R., Schutte, A.R., & Schöner, G. (2007). What does theoretical neuroscience have to offer the study of behavioral development? Insights from a dynamic field theory of spatial cognition. In J. Plumert & J.P. Spencer (Eds) *The Emerging Spatial Mind* (p. 320-361). New York: Oxford University Press.