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Book Review

Nonlinear Dynamics: Techniques and Applications in Psychology. By Richard A. Heath. Lawrence Erlbaum Associates, Mahwah, NJ, 2000, 379 p. + ix. ISBN 0-8058-3200-9.

It is a curious fact that although everyone recognizes that psychological experience possesses a time dimension, psychology has virtually ignored this fact, judging by the choice of experimental designs and analytical tools. Certainly these tools, such as ARIMA, MANOVA, factor analysis, have achieved a very high level of sophistication, including the introduction of methods for dealing with inherent nonlinearities among the dependent variables. Nevertheless, the models constructed are static, frozen in time, mere snapshots of our psychological world.

Recognition of the importance of the time dimension has come relatively late to psychology, essentially within the past twenty years. Spurred by its success in the physical sciences, researchers began to apply ideas emanating from the study of dynamics, particularly nonlinear dynamics, to problems relevant to psychology, such as the structure of the electroencephalogram, the structure of psychological development, and the dynamics of organizations. Most researchers worked in isolation, but were given a boost ten years ago with the formation of the Society for Chaos Theory in Psychology & Life Sciences, which brought these researchers together into a common forum for the dissemination of their work and ideas and in particular, their methods.

Scientific research advances on the shoulders of its methodologies, and it is critical for its researchers to have up to date and detailed descriptions of these methodologies in order for the field to grow. Sadly, the teaching of quantitative methods in the standard psychology curriculum is limited to static statistical methodologies, without much exposure to other branches of mathematics and almost certainly without exposure to dynamical systems theory in any form.

To be fair, the lack may be due in part to the relative absence of accessible textbooks. To my knowledge there are only two *: A Visual Introduction to*

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Dynamical Systems Theory for Psychology by F. Abraham, R. Abraham, and C.D. Shaw (1990), and *Understanding Nonlinear Dynamics* by D. Kaplan and L. Glass (1995). Although these two books provide an excellent introduction to the mathematics underlying dynamical systems approaches, they have little detailed information about the related methods that are to be applied to the analysis of real experimental data. Thus the average psychological researcher is forced to attempt to master the vast and technically challenging literature available in the mathematics, physics, and engineering journals. At least that has been the case until now. Finally, however, researchers have at their disposal an accessible, thorough and comprehensive handbook of nonlinear dynamical systems methods, specifically oriented towards applications in psychology.

In ten chapters, Heath surveys all of the most important areas being applied in current research. The range is truly impressive, as is the adherence to examples based either on real psychological experiments or on simulations motivated by psychological questions. Examples include the tracking of anxiety ratings during forty sessions of psychotherapy, the analysis of temporal correlations in time series of response times in a line length discrimination experiment, the analysis of interkeypress data from an extended typing study, the analysis of a two channel tracking task, the analysis of handwriting velocity, the analysis of time series of EEG and ECG signals, and neural network simulations. In almost every case, the examples are based upon real data, which lends an important air of credibility as well as relevance to the text.

The first two chapters cover fairly standard approaches to the linear analysis of time series data using ARIMA, autocorrelation, power spectrum, and, in the case of nonstationary time series, adaptive Kalman filtering.

Nonlinearity is introduced in Chapters 3 and 4 in the context of the creation of system identification models using transfer functions to relate stimulus and response. In Chapter 3, Heath compares and contrasts linear and nonlinear approaches using the method of nonlinear system identification developed by Marmarelis and Marmarelis in 1978. In Chapter 4, Heath presents a generalization of this approach that includes a learning component based upon a gradient decent minimization procedure, in order to obtain an improved fit between model and data.

These first four chapters take what might be described as a systems theory approach to data analysis, since these methods find their origins in the systems literature. The discussion of nonlinear dynamical systems methods properly begins in Chapter 5 and extends through to Chapter 8.

Chapter 5 concerns itself with the graphical representation of data, beginning with the phase space, indisputably the heart of nonlinear dynamical systems methods. This chapter is notable for its extensive discussion of

recurrence plots, which provide a quick and easy method for visually detecting regularities in the temporal structure of a time series.

Chapter 6 describes the now classic methods for calculating various indices that measure different geometrical features of a system's trajectory. These include correlation dimension, Lyapunov exponents, entropy, BDS statistics. Unfortunately no mention is made of LZ complexity, Hurst exponents, and only brief mention is given of methods suitable for short time series, such as that of exceptional events, and the detection of unstable periodic orbits. In spite of these minor limitations, the discussion thoroughly examines both the strengths and the weaknesses of these techniques.

This discussion is expanded in Chapter 7, which deals with the problem of noise reduction and the use of hypothesis testing. This chapter is essential reading, since no analysis based upon nonlinear dynamical systems methods should be accepted for publication unless specific attention has been paid in the analysis to the handling of noise and unless suitable hypothesis testing has been done to rule out alternative interpretations, especially the presence of correlated noise.

The final three chapters provide icing for the cake. Chapter 8 presents a fascinating discussion of the use of chaos control techniques in the modeling of human information processing and exposes the reader to a cutting edge line of research. Chapter 9 introduces the reader to models of human information processing that are based on a closely related field, that of complex systems theory. Though still in its infancy, complex systems theory promises to surpass nonlinear dynamical systems theory in its relevance to psychology, and although this introduction is brief, it gives the reader a tantalizing taste of what the future may hold in store. Chapter 10 provides a wealth of additional examples of the applications of nonlinear dynamical systems methods to real psychological experiments. It further serves to convince the reader of the usefulness of these techniques.

Heath describes this book as being a reference handbook for research psychologists and with that I heartily agree. The book is densely written and background material is minimally described, if at all. Heath states that a first quantitative course is sufficient background to read this book, but if so, then I am forced to admit that the Australian education system is far superior to that in North America. Heath assumes a mathematical background that in my experience is sorely lacking in North American psychology curricula, and which is likely to remain so for some time to come. The reader is well advised to have a copy of Abraham et al. or Kaplan and Glass handy to help to clarify basic concepts and provide the necessary mathematical background.

Heath has done the psychology community an inestimable service. This book should be on the reference shelf of every practicing researcher, not just in psychology but in the social sciences as well. I also think that it should

be required reading for any advanced course in quantitative methods, particularly at the graduate level. I hope that future editions of this book will include some of the more recent developments in this field, and so provide an enduring resource for future generations of psychology researchers.

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