Chapman & Hall / CRT Statistics Books: Proposal

## Proposed title

**Visualizing Multivariate Data and Models in R**

## Author

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## Contents

An in-progress outline with some description is attached. Reviewers who wish to see the current state can visit the working draft, <https://friendly.github.io/Vis-MLM-book/> or the GitHub repository, <https://github.com/friendly/vis-MLM-book>

## Rationale

This book is about graphical methods for multivariate data, and their uses in understanding relationships, particularly when there are several aspects to be considered together in multiple response models such as multivariate analysis of variance and multivariate multiple regression. It reflects topics I have been working on for over 30 years, now finding their way into a (hopefully) coherent presentation in book form.

Data visualization methods for statistical analysis are well-developed for simple linear models with a single outcome variable. However, with applied research in the social and behavioral sciences, it is often the case that the phenomena of interest (e.g., depression, job satisfaction, academic achievement, childhood ADHD disorders, etc.) can be measured in several different ways or related aspects. For example, if academic achievement can be measured for adolescents by reading, mathematics, science and history scores, how do predictors such as parental encouragement, school environment and socioeconomic status affect all these outcomes? In a similar way? In different ways? In such cases, much more can be understood from a multivariate approach that considers the correlations among the outcomes. Yet, sadly, researchers typically examine the outcomes one by one which often only tells part of the data story.

The statistical leap from univariate to multivariate methods is quite simple because the classical models for ANOVA and regression:

* Generalize directly to analogous models for MANOVA and multivariate regression,
* Statistical multivariate tests are straightforward extensions of standard *F*- and *t*-tests but give richer detail about the relationships among response variables.
* Univariate intervals become ellipses (and ellipsoids!), showing location, covariation, and precision.

The book brings together a collection of novel techniques I (and others) have developed over the past 15 years and implemented in mature R packages. Some key **substantive features** of the book are:

* Statistical data visualization is cast in a general framework by **goal** (see the data, visualize a model, diagnose problems), rather than a categorization by graphic types. It is best informed by principles and goals of **communication**, for example making graphic comparison easy and ordering factors and variables according to what should be seen (*effect ordering*).
* Data visualization is seen as a combination of **exposure**—plotting the raw data--- and **summarization**--- plotting statistical summaries--- to highlight what should be noticed. For example, data ellipses and confidence ellipses are widely used as simple, effective summaries of data and fitted model parameters. When the data is complex, the idea of *visual thinning* can be used to balance the trade-off.
* These graphical tools can be used to understand or explain a wide variety of statistical concepts, phenomena (collinearity in regression), and paradoxes such as Simpson’s paradox, effects of measurement error, and so forth.
* The HE (“hypothesis – error”) plot framework provides a simple way to understand the results of statistical tests and the relations among response outcomes in the multivariate linear model.
* Dimension reduction techniques such as PCA and discriminant analysis are presented as “multivariate juicers,” able to squeeze the important information in high-dimensional data into informative two-dimensional views. Biplots provide a simple way to depict multivariate data in PCA space. Canonical HE plots project the information about effects of predictors on outcomes from data space into the low-dimensional space that shows the most important relationships, together with their associations with the observed response variables.

Some key **pedagogical features** are:

* Conceptual diagrams are used throughout the book to illustrate the main ideas behind statistical and graphical methods.
* Infoboxes or “callouts” are used to explain related ideas to interfere little with the main flow of the narrative. For example, I will feature “History Corner” callouts to relate modern methods to their historical antecedents so that readers can appreciate how these methods arose.
* All examples are “live,” in the sense that they are directly produced by the R code in the book. The online version will allow these to be either shown directly in the text or toggled on/off by the reader.
* The book will be supplemented by extensive online resources, including datasets, R functions and scripts for many of the examples. Online appendices will be used to go beyond the material that comfortably fits within the book.

## Related books

There are several textbooks and monographs on multivariate data analysis, but none focus mainly on data visualization and graphical methods. Most often, such books for the social sciences to use SPSS or SAS, but not to great advantage in visual understanding. Everitt & Hothorn (2011) and Schumacker (2015) do use R, but not with any incisive graphics. The proposed book is unique, in that it provides a coherent view of multivariate data and models, centered on visualization for understanding and explaining effects, and implemented in modern R packages.

A few texts on multivariate methods are:

* Everitt, B., & Hothorn, T. (2011). *An Introduction to Applied Multivariate Analysis with R*. Springer New York
* Johnson, R. A. & Wichern, D. W. (2015). *Applied Multivariate Statistical Analysis*. Pearson.
* Meyers, L. S. Gamst, G. & A. J. Guarino (2016), *Applied Multivariate Research: Design and Interpretation*. 3rd Ed. Sage.
* Schumacker, R. (2015). *Using R With Multivariate Statistics.* Sage.
* Tabachnick, B. G., & Fidell, L. S. (2019). *Using Multivariate Statistics* (7 ed.). Pearson.
* Timm, N. H. (1975). *Multivariate Analysis with Applications in Education and Psychology*. Wadsworth (Brooks/Cole)

## Audience

This book is aimed at advanced undergraduates, graduate students and researchers wishing to learn and apply multivariate techniques. It is assumed that the reader has a basic understanding of statistical concepts at least at an intermediate undergraduate level including material on univariate linear models (ANOVA, multiple regression), for example at the level of Mendenhall & Sincich (2003) or Neter et al. (1990). The mathematical level will also be intermediate, in that formulas are used where necessary and matrix notation where it simplifies presentation. But there will be no proofs or derivations, and many mathematical results will be illustrated visually or conceptually.

## It is also assumed that the reader has at least a basic knowledge of the R language and environment,

## including interacting with the R console (RGui forWindows, R.app for Mac OS X) or preferably the RStudio environment; they should also understand using R functions in packages, getting help for these from R, etc. Online supplements will provide helpful resources for those who need them.

## Production

At this stage of writing, it is difficult to predict the number of pages, but I expect it to be in the range 300-400, with perhaps 100 figures. Because this is a book on data graphics, color will be essential throughout.

The book is being written using RStudio, Rmarkdown and Quarto. In writing, I’m using primarily HTML format and would like to make pre-publication drafts publicly available for comment and suggestions by colleagues. I expect to be able to have this translated to LaTeX, using the standard CRC krantz.cls, though some assistance with this might be necessary.

I expect to complete a first draft of the book in the Fall of 2024.

## Reviews

The following are potential reviewers for the book proposal. Of these, Fox & Monette are colleagues with whom I have worked before, but I entirely trust their judgment.

John Fox, [jfox@mcmaster.ca](mailto:jfox@mcmaster.ca)

Georges Monette, [georges@yorku.ca](mailto:georges@yorku.ca)

Dianne Cook, [dicook@monash.edu](mailto:dicook@monash.edu)

Wayne Oldford, [rwoldford@uwaterloo.ca](mailto:rwoldford@uwaterloo.ca)

Antony Unwin, [unwin@math.uni-augsburg.de](mailto:unwin@math.uni-augsburg.de)

## Marketing

Key features: described above

Keywords: data visualization; multivariate analysis; data analysis; statistics; R

Markets:

The book will be written so that it can be used as a primary or secondary text in courses dealing with multivariate data analysis at the upper undergraduate and graduate levels. For example, I used to teach a graduate course, 6140: *Multivariate Data Analysis* in the Quantitative Methods area in Psychology at York, where this book could serve as the main text.

* STA07A-Statistics-Statistical Theory & Methods
* STA12A-Statistics-Statistics for the Social and Behavioral Sciences
* CMS08-Computer Science & Engineering-Visualization
* Statistics: Biostatistics and Epidemiology