Preface to the Second Edition

Since writing the first edition of *Design and Analysis of Experiments*, there have been a number of additions to the research investigator's toolbox. In this second edition, we have incorporated a few of these modern topics.

Small screening designs are now becoming prevalent in industry for aiding the search for a few influential factors from amongst a large pool of factors of potential interest. In Chap. 15, we have expanded the material on saturated designs and introduced the topic of *supersaturated designs* which have fewer observations than the number of factors being investigated. We have illustrated that useful information can be gleaned about influential factors through the use of supersaturated designs even though their contrast estimators are correlated. When curvature is of interest, we have described *definitive screening designs* which have only recently been introduced in the literature, and which allow second order effects to be measured while retaining independence of linear main effects and requiring barely more than twice as many observations as factors.

Another modern set of tools, now used widely in areas such as biomedical and materials engineering, the physical sciences, and the life sciences, is that of *computer experiments*. To give a flavor of this topic, a new Chap. 20 has been added. Computer experiments are typically used when a mathematical description of a physical process is available, but a physical experiment cannot be run for ethical or cost reasons. We have discussed the major issues in both the design and analysis of computer experiments. While the complete treatment of the theoretical background for the analysis is beyond the scope of this book, we have provided enough technical details of the statistical model, as well as an intuitive explanation, to make the analysis accessible to the intended reader. We have also provided computer code needed for both design and analysis.

Chapter 19 has been expanded to include two new experiments involving split-plot designs from the discipline of human factors engineering. In one case, imbalance due to lost data, coupled with a mixed model, motivates introduction of restricted-maximum-likelihood-based methods implemented in the computer software sections, including a comparison of these methods to those based on least squares estimation.

It is now the case that analysis of variance and computation of confidence intervals is almost exclusively done by computer and rarely by hand. However, we have retained the basic material on these topics since it is

fundamental to the understanding of computer output. We have removed some of the more specialized details of least squares estimates from Chaps. 10–12 and canonical analysis details in Chap. 16, relying on the computer software sections to illustrate these.

SAS® software is still used widely in industry, but many university departments now teach the analysis of data using R (R Development Core Team, 2017). This is a command line software for statistical computing and graphics that is freely available on the web. Consequently, we have made a major addition to the book by including sections illustrating the use of R software for each chapter. These sections run parallel to the "Using SAS Software" sections, retained from the first edition.

A few additions have been made to the "Using SAS Software" sections. For example, in Chap. 11, `PROC OPTEX` has been included for generation of efficient block designs. `PROC MIXED` is utilized in Chap. 5 to implement Satterthwaite's method, and also in Chaps. 17–19 to estimate standard errors involving composite variance estimates, and in Chap. 19 to implement *restricted maximum likelihood estimation* given imbalanced data and mixed models.

We have updated the SAS output[1], showing this as reproductions of PC output windows generated by each program. The SAS programs presented can be run on a PC or in a command line environment such as unix, although the latter would use `PROC PLOT` rather than the graphics `PROC SGPLOT`.

Some minor modifications have been made to a few other chapters from the first edition. For example, for assessing which contrasts are non-negligible in single replicate or fractional factorial experiments, we have replaced normal probability plots by *half-normal probability plots* (Chaps. 7, 13 and 15). The reason for this change is that contrast signs are dependent upon which level of the factor is labeled as the high level and which is labeled as the low level. Half-normal plots remove this potential arbitrariness by plotting the absolute values of the contrast estimates against "half-normal scores".

Section 7.6 in the first edition on the control of noise variability and Taguchi experiments has been removed, while the corresponding material in Chap. 15 has been expanded. On teaching the material, we found it preferable to have information on mixed arrays, product arrays, and their analysis, in one location. The selection of multiple comparison methods in Chap. 4 has been shortened to include only those methods that were used constantly throughout the book. Thus, we removed the method of multiple comparisons with the best, which was not illustrated often; however, this method remains appropriate and valid for many situations in practice.

Some of the worked examples in Chap. 10 have been replaced with newer experiments, and new worked examples added to Chaps. 15 and 19. Some new exercises have been added to many chapters. These either replace

[1]The output in our "Using SAS Software" sections was generated using SAS software Version 9.3 of the SAS System for PC. Copyright © SAS 2012 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

exercises from the first edition or have been added at the end of the exercise list. All other first edition exercises retain their same numbers in this second edition.

A new website http://www.wright.edu/~dan.voss/DeanVossDraguljic.html has been set up for the second edition. This contains material similar to that on the website for the first edition, including datasets for examples and exercises, SAS and R programs, and any corrections.

We continue to owe a debt of gratitude to many. We extend our thanks to all the many students at The Ohio State University and Wright State University who provided imaginative and interesting experiments and gave us permission to include their projects. We thank all the readers who notified us of errors in the first edition and we hope that we have remembered to include all the corrections. We will be equally grateful to readers of the second edition for notifying us of any newly introduced errors. We are indebted to Russell Lenth for updating the R package `lsmeans` to encompass all the multiple comparisons procedures used in this book. We are grateful to the editorial staff at Springer, especially Rebekah McClure and Hannah Bracken, who were always available to give advice and answer our questions quickly and in detail.

Finally, we extend our love and gratitude to Jeff, Nancy, Tom, Jimmy, Linda, Luka, Nikola, Marija and Anika.

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