

Preface

Why you should read this book

A little effort (this is a short book) will help you design better experiments, and designing better experiments will make your life richer and happier and possibly easier! First of all, collecting data to test theories is the very essence of science—no matter what sort of scientist you aim to be, you really need to be able to design good experiments yourself and/or evaluate other scientists' experiments. So don't fool yourself by pretending experimental design doesn't matter to you. We are confident that whether you have never designed an experiment before or whether you have been doing it for some time, there are ideas in this book that will improve your confidence and ability to design and evaluate data collection. Don't fool yourself into thinking that experimental design is an abstruse exercise in applied maths that is beyond you. Flick through this book, there is barely an equation, and we have spent four editions honing our explanations to make them as clear as possible—without a shadow of doubt, if you read this book, then you will understand it and you will be a better scientist for it. At the opposite extreme, be wary of thinking that experimental design is so simple that this book isn't worth your time. If that were true then the world would not be littered with student lab reports with low grades because the student made basic mistakes in experimental design, and manuscripts by professional scientists that will never become published scientific papers for the same reason. If you read this book then for the rest of your scientific life you will design experiments that give clearer answers to more interesting questions, using less of your time, fewer resources, and simpler statistics. Not only that, but you will get more from every scientific paper you read and every scientific talk you listen to. The upshot of these benefits is that you will be a better scientist and a happier person. Given all that, the question really is why on Earth should you not read this book?

Why not to read this book

If you want a book on statistics this is not it. We do explore links between experimental design and statistical analysis throughout the book, but this book has very little to teach you about formal statistics. If you want an encyclopaedic tome covering every possible experimental design, then we cannot offer that either: that would be a book at least ten times the size. What we do offer is to give you an understanding of the underlying philosophy common to all experimental designs, and a clear introduction to terminology—these will help you to read books and papers that offer complex designs, but here we only look in depth at relatively simple designs. But 'simple' does not mean 'toy'—the latest issues of the very best scientific journals have articles based on experiments no more complicated than the ones we cover in this book, and

most scientists will go through their whole career without having to delve into more complicated designs.

Why we felt the need to produce yet another edition of the book

In truth, some typos aside, there is nothing that was downright wrong in any of our previous editions. With each new edition we have been responsive to feedback from readers and from our own development as scientists to come up with improvements in how we communicate the basic ideas of experimental design. This revision has been much more sweeping than the previous two. We have extensively reorganized and rewritten so as to emphasize linkages between different aspects of experimental design more effectively. Thus we think this book should function both to give you quick answers when you have a very focused question and to give you a solid overview of the overarching concepts of experimental design. From that perspective, we hope that you read the book at least once from cover to cover, and then keep it to dip into quickly as and when required.

Learning features

Key definitions

There is a lot of jargon associated with experimental design and statistical analysis. We have not tried to avoid this. Indeed, we have deliberately tried to introduce you to as much of the jargon as we can. By being exposed to this jargon, we hope that it will become second nature to you to use—and understand—it. This should also make reading more advanced texts and scientific papers on experimental design less daunting. However, to make negotiating the minefield of jargon more straightforward, we have increased the number of definitions of key terms provided and increased the level of detail in all definitions. Each key word or phrase is emboldened at the point where we first use it, and is given a clear definition in a box nearby.

Statistics boxes

To emphasize the important link between good experimental design and statistics we now include a number of statistical boxes. These boxes should help you to see how thinking about design helps you think about statistics and vice versa. We have added the boxes at points where we think that keeping the statistics in mind is particularly useful and include pointers in the main text to each box.

Reverse causation

The second problem of correlational studies is **reverse causation**. This can arise if a relationship between factors A and B is mistakenly assumed to be A influences factor B, when in fact it is change in B that drives change in A.

For example, imagine a survey shows that those who consider themselves successful also consider themselves to have financial problems. It is tempting to conclude that a bad habit (being successful) causes financial problems. However, the reverse is true: people who have financial problems may be more likely to turn to drugs (perhaps as a way to temporarily escape their problems). In this case, we should consider the first explanation to be the more plausible. Reverse causation is at least plausible, indeed both directions are plausible.

Reverse causation is mistakenly concluding that variable A influences variable B when actually it is B that influences A.

STATISTICS BOX 3.1 Generalizing from a study

An important issue in the interpretation of a study is how widely applicable the results of the study are likely to be. That is, how safely can you generalize from the particular set of subjects used in your study to the wider world? Imagine that we measured the height of 100 adult males and females and found that the mean height was 1.75 m. Is this average 1.75 m taller than we or anyone else are? It is not clear that our sample were not specific individuals. Rather, we are interested in what is particularly interesting in studies from studies of the sample. This becomes easy if we can generalize from the sample to the population from which our sample was drawn. Our aim was to create a sample that was representative of the population. If we have more data, then we should be able to generalize more safely.

Self-test questions

The more you think about experimental design, the easier designing robust experiments becomes. To get you thinking while you are reading this book, we include a number of self-test questions in every chapter. Often there will not be a clear right or wrong answer to a question, but suggested answers to all questions can be found at the back of the book.

Take-home messages

To help to consolidate your thinking, we end most sections with a take-home message. By including these throughout the text we hope to give you an immediate opportunity to evaluate your understanding of a section before moving on.

Boxes and online supplementary material

We have aimed to produce a book that can be read from cover to cover, and so have tried to keep unnecessary details out of the main text. However, in areas where we feel that more details or more examples will lead to a fuller understanding of a concept we have included supplementary boxes. Where there is (to our mind) really interesting material that will not be strictly relevant to all readers, we have not included that material in the book itself, but lodged it on an associated website (www.oxford-textbooks.co.uk/orc/ruxton4e/). We point to this supplementary material at appropriate points throughout the book.

Chapter outlines

Most chapters begin with an outline of the main points covered by that chapter. These outlines should help you to prepare for what is ahead. The outlines will also provide an easy way for you to dip in and out of the book during subsequent readings.

Chapter summaries

Every chapter finishes with a summary of the most important points covered in that chapter. By reading through this list you should be able to reassure yourself that you have got everything out of the chapter that you can, or go back and read sections again that are not yet clear in your mind.

There is a connection between the amount of ice cream sold in England and the number of driving accidents. This is unlikely to be a direct effect, but heavy consumption of ice cream leads to muscle clamping or loss of consciousness among summer motorists. More likely, a third variable can work when the weather is hot: ice creams are sold but also (and separately) more cars are driven, and more cars are driven by those who are not driving soberly. In short, this variable may be difficult to be confident that heavy observation of an unmanipulated system is really due to the factors measured and not due to confounding with some other unmeasured variable. It may be a matter of re-examining problems with this variable to carry out manipulations.

Q 3.1 In a survey of 1000 killed badgers it was found that those with higher levels of intestinal parasites had lower bodyweights: can we safely conclude that intestinal parasites cause weight loss? Is there a plausible third variable that could explain this?

Sample size requires you to consider variability. This might occur because increasing your sample size requires you to consider more domestic chicks from two different suppliers rather than one; or two different suppliers for your petri dishes instead of one; or measure chicks rather than all in the same session.

➔ Anything we can do to reduce variation amongst our samples will increase the power of our study.

Dealing with variation through design

BOX 6.1: An example of statistical power calculations returning to hens' eggs

In Chapter 4 we used the example of the effects of GM feed on egg shell thickness and replication (see Box 4.1). Let's return to this example to think about variation and power. For the sake of this example we are going to assume the GM grain really does have an effect on the thickness of egg shells, reducing an average reduction of 0.4 mm. Or to put it in terms of standard eggs, we assume that the feed causes the population mean of GM eggs to be different from the population mean of standard eggs. Of course, our investigator does not know this, but a statistician can use the usual test to determine whether GM feed affects shell thickness.

See Section 2.1 of the supplementary material for the importance of a focused research question, you might even a few minutes making unfocused observations of the world around you. You should be striving to address the most interesting questions, not as many questions as you can. Darwin, Einstein, and famous because they solved more problems than anyone else. So take the time to think about what problems are. We are not promising that you'll become as famous as them, but the chances will increase.

Flow chart

The exact process of designing an experiment will vary considerably between studies. Nevertheless, there are key stages in the design process that will apply to most, if not all, studies. The flow chart at the end of this book is intended to summarize and guide you through the main stages of designing an experiment. We have indicated at each point in the chart the sections of the book that are most relevant.