

# CONTENTS

<b>PREFACE</b>	<b>XV</b>
<b>HOW TO USE THIS BOOK</b>	<b>XIX</b>
<b>THANK YOU</b>	<b>XXV</b>
<b>DEDICATION</b>	<b>XXVII</b>
<b>SYMBOLS USED IN THIS BOOK</b>	<b>XXIX</b>
<b>A BRIEF MATHS OVERVIEW</b>	<b>XXXI</b>
<b>1 WHY IS MY EVIL LECTURER FORCING ME TO LEARN STATISTICS?</b>	<b>1</b>
<b>2 THE SPINE OF STATISTICS</b>	<b>49</b>
<b>3 THE PHOENIX OF STATISTICS</b>	<b>107</b>
<b>4 ARGH! ARGH!STUDIO AND QUARTO</b>	<b>151</b>
<b>5 DESCRIBING AND VISUALIZING DATA</b>	<b>241</b>
<b>6 THE BEAST OF BIAS</b>	<b>321</b>
<b>7 CORRELATION</b>	<b>403</b>
<b>8 THE LINEAR MODEL (REGRESSION)</b>	<b>445</b>
<b>9 CATEGORICAL PREDICTORS: COMPARING TWO MEANS</b>	<b>515</b>
<b>10 A TALE OF THREE Ms: MODERATION, MEDIATION AND MISSINGNESS</b>	<b>557</b>
<b>11 GLM 1: COMPARING SEVERAL INDEPENDENT MEANS</b>	<b>609</b>
<b>12 GLM 2: COMPARING MEANS ADJUSTED FOR OTHER PREDICTORS (ANALYSIS OF COVARIANCE)</b>	<b>675</b>
<b>13 GLM 3: FACTORIAL DESIGNS</b>	<b>711</b>
<b>14 GLM 4: MULTILEVEL LINEAR MODELS</b>	<b>761</b>
<b>15 GLM 5: REPEATED-MEASURES DESIGNS</b>	<b>821</b>
<b>16 GLM 6: MIXED DESIGNS</b>	<b>867</b>
<b>17 EXPLORATORY FACTOR ANALYSIS</b>	<b>905</b>
<b>18 CATEGORICAL OUTCOMES: CHI-SQUARE AND LOGLINEAR ANALYSIS</b>	<b>977</b>
<b>19 CATEGORICAL OUTCOMES: LOGISTIC REGRESSION</b>	<b>1025</b>
<b>EPILOGUE</b>	<b>1075</b>
<b>APPENDIX</b>	<b>1079</b>
<b>GLOSSARY</b>	<b>1091</b>
<b>REFERENCES</b>	<b>1125</b>
<b>INDEX</b>	<b>1145</b>

# EXTENDED CONTENTS

<b>PREFACE</b>	<b>XV</b>
<b>HOW TO USE THIS BOOK</b>	<b>XIX</b>
<b>THANK YOU</b>	<b>XXV</b>
<b>DEDICATION</b>	<b>XXVII</b>
<b>SYMBOLS USED IN THIS BOOK</b>	<b>XXIX</b>
<b>A BRIEF MATHS OVERVIEW</b>	<b>XXXI</b>
<b>1 WHY IS MY EVIL LECTURER FORCING ME TO LEARN STATISTICS?</b>	<b>1</b>
1.1 What the hell am I doing here? I don't belong here	3
1.2 The research process	3
1.3 Initial observation: finding something that needs explaining	4
1.4 Generating and testing theories and hypotheses	5
1.5 Collecting data: measurement	9
1.6 Collecting data: research design	16
1.7 Analysing data	22
1.8 Reporting data	41
1.9 Jane and Brian's story	45
1.10 What next?	45
1.11 Key terms that I've discovered	45
Smart Alex's Tasks	46
<b>2 THE SPINE OF STATISTICS</b>	<b>49</b>
2.1 What will this chapter tell me?	50
2.2 What is the SPINE of statistics?	51
2.3 Statistical models	51
2.4 Populations and samples	55
2.5 The linear model	57
2.6 P is for parameters	59
2.7 E is for estimating parameters	66
2.8 S is for standard error	71
2.9 I is for (confidence) interval	74
2.10 N is for null hypothesis significance testing	80
2.11 Reporting significance tests	100
2.12 Jane and Brian's story	102
2.13 What next?	103
2.14 Key terms that I've discovered	104
Smart Alex's Tasks	104

<b>3</b>	<b>THE PHOENIX OF STATISTICS</b>	<b>107</b>
3.1	What will this chapter tell me?	108
3.2	Problems with NHST	109
3.3	NHST as part of wider problems with science	119
3.4	A phoenix from the EMBERS	125
3.5	Sense, and how to use it	126
3.6	Preregistering research and open science	127
3.7	Effect sizes	128
3.8	Bayesian approaches	137
3.9	Reporting effect sizes and Bayes factors	146
3.10	Jane and Brian's story	147
3.11	What next?	147
3.12	Key terms that I've discovered	149
	Smart Alex's Tasks	149
<b>4</b>	<b>ARGH! ARGH!STUDIO AND QUARTO</b>	<b>151</b>
4.1	What will this chapter tell me?	152
4.2	Packages used in this chapter	153
4.3	What is R?	153
4.4	Getting started	156
4.5	A tour of RStudio	161
4.6	Workflow	169
4.7	Quarto	173
4.8	Code fundamentals	187
4.9	Writing code in Quarto	199
4.10	Workflow for the rest of the book	234
4.11	Jane and Brian's story	236
4.12	What next?	236
4.13	Key terms that I've discovered	237
	Smart Alex's Tasks	238
<b>5</b>	<b>DESCRIBING AND VISUALIZING DATA</b>	<b>241</b>
5.1	What will this chapter tell me?	242
5.2	Getting started	243
5.3	Describing data	243
5.4	The art of visualizing data	253
5.5	Introducing <i>ggplot2</i>	256
5.6	Histograms	275
5.7	Frequency polygons	281
5.8	Boxplots (box-whisker diagrams)	283
5.9	Plotting means	291
5.10	Repeated measures designs	302
5.11	Line plots and mixed designs	305
5.12	Graphing relationships: the scatterplot	308
5.13	Brian and Jane's story	317
5.14	What next?	318
5.15	Key terms that I've discovered	319
	Smart Alex's Tasks	319

<b>6</b>	<b>THE BEAST OF BIAS</b>	<b>321</b>
6.1	What will this chapter tell me?	322
6.2	Getting started	323
6.3	Descent into statistics hell	323
6.4	What is bias?	344
6.5	Outliers	345
6.6	Overview of assumptions	348
6.7	Linearity and additivity	349
6.8	Spherical errors	349
6.9	Normally distributed something or other	354
6.10	Checking for bias and describing data	358
6.11	Reducing bias with robust methods	390
6.12	Jane and Brian's story	399
6.13	What next?	400
6.14	Key terms that I've discovered	401
	Smart Alex's Tasks	401
<b>7</b>	<b>CORRELATION</b>	<b>403</b>
7.1	What will this chapter tell me?	404
7.2	Getting started	405
7.3	Modelling relationships	405
7.4	Bivariate correlation	414
7.5	Partial and semi-partial correlation	431
7.6	Comparing correlations	435
7.7	Calculating the effect size	438
7.8	How to report correlation coefficients	438
7.9	Jane and Brian's story	439
7.10	What next?	441
7.11	Key terms that I've discovered	442
	Smart Alex's Tasks	442
<b>8</b>	<b>THE LINEAR MODEL (REGRESSION)</b>	<b>445</b>
8.1	What will this chapter tell me?	446
8.2	Getting started	447
8.3	The linear model (regression) ... again!	448
8.4	Bias in linear models	456
8.5	Generalizing the model	461
8.6	Sample size and the linear model	463
8.7	Fitting linear models: the general procedure	465
8.8	Using R to fit a linear model with one predictor	465
8.9	Interpreting a linear model with one predictor	470
8.10	The linear model with two or more predictors (multiple regression)	473
8.11	Using R to fit a linear model with several predictors	478
8.12	Interpreting a linear model with several predictors	482
8.13	Robust linear models	499
8.14	Bayesian regression	504

8.15	Reporting linear models	508
8.16	Jane and Brian's story	509
8.17	What next?	509
8.18	Key terms that I've discovered	511
	Smart Alex's Tasks	512
<b>9</b>	<b>CATEGORICAL PREDICTORS: COMPARING TWO MEANS</b>	<b>515</b>
9.1	What will this chapter tell me?	516
9.2	Getting started	517
9.3	Looking at differences	517
9.4	A mischievous example	519
9.5	Categorical predictors in the linear model	522
9.6	The <i>t</i> -test	524
9.7	Assumptions of the <i>t</i> -test	531
9.8	Comparing two means: general procedure	531
9.9	Comparing two independent means using R	532
9.10	Comparing two related means using R	542
9.11	Reporting comparisons between two means	551
9.12	Between groups or repeated measures?	552
9.13	Jane and Brian's story	552
9.14	What next?	553
9.15	Key terms that I've discovered	554
	Smart Alex's Tasks	554
<b>10</b>	<b>A TALE OF THREE Ms: MODERATION, MEDIATION AND MISSINGNESS</b>	<b>557</b>
10.1	What will this chapter tell me?	558
10.2	Getting started	559
10.3	Moderation: interactions in the linear model	559
10.4	Mediation	574
10.5	Missing data	591
10.6	Jane and Brian's story	606
10.7	What next?	606
10.8	Key terms that I've discovered	607
	Smart Alex's Tasks	608
<b>11</b>	<b>GLM 1: COMPARING SEVERAL INDEPENDENT MEANS</b>	<b>609</b>
11.1	What will this chapter tell me?	610
11.2	Getting started	611
11.3	A puppy-tastic example	611
11.4	Goodbye one-way ANOVA, hello linear model	613
11.5	Comparing several means with the linear model	615
11.6	Assumptions when comparing means	628
11.7	Planned contrasts (contrast coding)	630
11.8	<i>Post hoc</i> procedures	643
11.9	Effect sizes when comparing means	647
11.10	Comparing several means using R	648
11.11	Trend analysis	658

## EXTENDED CONTENTS

11.12	Robust comparisons of several means	661
11.13	Bayesian comparison of several means	666
11.14	Reporting results when comparing means	669
11.15	Jane and Brian's story	670
11.16	What next?	671
11.17	Key terms that I've discovered	672
	Smart Alex's Tasks	672
<b>12</b>	<b>GLM 2: COMPARING MEANS ADJUSTED FOR OTHER PREDICTORS (ANALYSIS OF COVARIANCE)</b>	<b>675</b>
12.1	What will this chapter tell me?	676
12.2	Getting started	677
12.3	Goodbye ANCOVA, hello general linear model	677
12.4	The <i>F</i> -statistic with multiple predictors	686
12.5	Adjusted means	689
12.6	Effect sizes for adjusted means	691
12.7	Fitting the model using R	692
12.8	Bayesian analysis with covariates	705
12.9	Reporting results	707
12.10	Jane and Brian's story	708
12.11	What next?	709
12.12	Key terms that I've discovered	709
	Smart Alex's Tasks	709
<b>13</b>	<b>GLM 3: FACTORIAL DESIGNS</b>	<b>711</b>
13.1	What will this chapter tell me?	712
13.2	Getting started	713
13.3	Factorial designs	713
13.4	A goggly example	715
13.5	Independent factorial designs and the linear model	716
13.6	Interpreting interaction plots	720
13.7	Simple effects analysis	723
13.8	<i>F</i> -statistics in factorial designs	724
13.9	Model assumptions in factorial designs	730
13.10	Factorial designs using R	731
13.11	Interpreting factorial designs	739
13.12	Robust models of factorial designs	751
13.13	Bayesian models of factorial designs	756
13.14	Reporting the results of factorial designs	756
13.15	Jane and Brian's story	758
13.16	What next?	759
13.17	Key terms that I've discovered	759
	Smart Alex's Tasks	759
<b>14</b>	<b>GLM 4: MULTILEVEL LINEAR MODELS</b>	<b>761</b>
14.1	What will this chapter tell me?	762
14.2	Getting started	763

14.3	Hierarchical data	764
14.4	Multilevel linear models	767
14.5	Practical issues	782
14.6	Multilevel modelling using R	791
14.7	How to report a multilevel model	815
14.8	A message from the octopus of inescapable despair	818
14.9	Jane and Brian's story	818
14.10	What next?	818
14.11	Key terms that I've discovered	820
	Smart Alex's Tasks	820
<b>15</b>	<b>GLM 5: REPEATED-MEASURES DESIGNS</b>	<b>821</b>
15.1	What will this chapter tell me?	822
15.2	Getting started	823
15.3	Emergency! The aliens are coming!	823
15.4	Growth models	823
15.5	Repeated-measures experiments	835
15.6	One-way experimental repeated-measures designs	843
15.7	A scented factorial repeated-measures design	852
15.8	Jane and Brian's story	862
15.9	What next?	864
15.10	Key terms that I've discovered	865
	Smart Alex's Tasks	866
<b>16</b>	<b>GLM 6: MIXED DESIGNS</b>	<b>867</b>
16.1	What will this chapter tell me?	868
16.2	Getting started	869
16.3	Mixed designs	869
16.4	Assumptions in mixed designs	870
16.5	Growth models for groups	871
16.6	Mixed experimental designs: a speed-dating example	879
16.7	Reporting the results of mixed designs	898
16.8	Jane and Brian's story	901
16.9	What next?	902
16.10	Key terms that I've discovered	902
	Smart Alex's Tasks	902
<b>17</b>	<b>EXPLORATORY FACTOR ANALYSIS</b>	<b>905</b>
17.1	What will this chapter tell me?	906
17.2	Getting started	907
17.3	When to use factor analysis	907
17.4	Factors and components	908
17.5	Discovering factors	915
17.6	An anxious example	927
17.7	How to report factor analysis	958
17.8	Reliability analysis	960
17.9	Reliability analysis using R	965

## EXTENDED CONTENTS

17.10	How to report reliability analysis	971
17.11	Jane and Brian's story	972
17.12	What next?	973
17.13	Key terms that I've discovered	973
	Smart Alex's Tasks	974
<b>18</b>	<b>CATEGORICAL OUTCOMES: CHI-SQUARE AND LOGLINEAR ANALYSIS</b>	<b>977</b>
18.1	What will this chapter tell me?	978
18.2	Getting started	979
18.3	Analysing categorical data	979
18.4	Associations between two categorical variables	979
18.5	Associations between several categorical variables: loglinear analysis	989
18.6	Assumptions when analysing categorical data	992
18.7	General procedure for analysing categorical outcomes	993
18.8	Doing chi-square using R	994
18.9	Loglinear analysis using R	1009
18.10	Reporting the results of loglinear analysis	1020
18.11	Jane and Brian's story	1021
18.12	What next?	1022
18.13	Key terms that I've discovered	1023
	Smart Alex's Tasks	1023
<b>19</b>	<b>CATEGORICAL OUTCOMES: LOGISTIC REGRESSION</b>	<b>1025</b>
19.1	What will this chapter tell me?	1026
19.2	Getting started	1027
19.3	What is logistic regression?	1027
19.4	Theory of logistic regression	1028
19.5	Sources of bias and common problems	1039
19.6	Logistic regression using R	1043
19.7	Interactions in logistic regression: a sporty example	1060
19.8	Reporting logistic regression	1070
19.9	Jane and Brian's story	1071
19.10	What next?	1072
19.11	Key terms that I've discovered	1073
	Smart Alex's Tasks	1073
	<b>EPILOGUE</b>	<b>1075</b>
	<b>APPENDIX</b>	<b>1079</b>
	<b>GLOSSARY</b>	<b>1091</b>
	<b>REFERENCES</b>	<b>1125</b>
	<b>INDEX</b>	<b>1145</b>