

Contents

List of tables	xv
List of figures	xvii
Preface to the Second Edition	xxvii
Preface to the First Edition	xxix
Acknowledgments	xxxi
1 Introduction	1
1.1 Read me first	1
1.2 The GSS dataset	4
1.2.1 Income	5
1.2.2 Age	6
1.2.3 Education	10
1.2.4 Gender	12
1.3 The pain datasets	12
1.4 The optimism datasets	13
1.5 The school datasets	13
1.6 The sleep datasets	13
1.7 Overview of the book	13
I Continuous predictors	17
2 Continuous predictors: Linear	19
2.1 Chapter overview	19
2.2 Simple linear regression	19
2.2.1 Computing predicted means using the margins command .	22
2.2.2 Graphing predicted means using the marginsplot command	24
2.3 Multiple regression	27

2.3.1	Computing adjusted means using the margins command	28
2.3.2	Some technical details about adjusted means	30
2.3.3	Graphing adjusted means using the marginsplot command	31
2.4	Checking for nonlinearity graphically	32
2.4.1	Using scatterplots to check for nonlinearity	33
2.4.2	Checking for nonlinearity using residuals	33
2.4.3	Checking for nonlinearity using locally weighted smoother	35
2.4.4	Graphing outcome mean at each level of predictor	36
2.4.5	Summary	39
2.5	Checking for nonlinearity analytically	39
2.5.1	Adding power terms	40
2.5.2	Using factor variables	42
2.6	Summary	46
3	Continuous predictors: Polynomials	49
3.1	Chapter overview	49
3.2	Quadratic (squared) terms	49
3.2.1	Overview	49
3.2.2	Examples	53
3.3	Cubic (third power) terms	59
3.3.1	Overview	59
3.3.2	Examples	60
3.4	Fractional polynomial regression	66
3.4.1	Overview	66
3.4.2	Example using fractional polynomial regression	70
3.5	Main effects with polynomial terms	79
3.6	Summary	81
4	Continuous predictors: Piecewise models	83
4.1	Chapter overview	83
4.2	Introduction to piecewise regression models	84
4.3	Piecewise with one known knot	86

4.3.1	Overview	86
4.3.2	Examples using the GSS	87
4.4	Piecewise with two known knots	95
4.4.1	Overview	95
4.4.2	Examples using the GSS	95
4.5	Piecewise with one knot and one jump	100
4.5.1	Overview	100
4.5.2	Examples using the GSS	101
4.6	Piecewise with two knots and two jumps	106
4.6.1	Overview	106
4.6.2	Examples using the GSS	106
4.7	Piecewise with an unknown knot	113
4.8	Piecewise model with multiple unknown knots	117
4.9	Piecewise models and the marginsplot command	124
4.10	Automating graphs of piecewise models	127
4.11	Summary	130
5	Continuous by continuous interactions	131
5.1	Chapter overview	131
5.2	Linear by linear interactions	131
5.2.1	Overview	131
5.2.2	Example using GSS data	136
5.2.3	Interpreting the interaction in terms of age	137
5.2.4	Interpreting the interaction in terms of education	139
5.2.5	Interpreting the interaction in terms of age slope	141
5.2.6	Interpreting the interaction in terms of the educ slope	142
5.3	Linear by quadratic interactions	144
5.3.1	Overview	144
5.3.2	Example using GSS data	147
5.4	Summary	152

6	Continuous by continuous by continuous interactions	153
6.1	Chapter overview	153
6.2	Overview	153
6.3	Examples using the GSS data	158
6.3.1	A model without a three-way interaction	158
6.3.2	A three-way interaction model	162
6.4	Summary	169
II	Categorical predictors	171
7	Categorical predictors	173
7.1	Chapter overview	173
7.2	Comparing two groups using a t test	174
7.3	More groups and more predictors	175
7.4	Overview of contrast operators	181
7.5	Compare each group against a reference group	182
7.5.1	Selecting a specific contrast	183
7.5.2	Selecting a different reference group	184
7.5.3	Selecting a contrast and reference group	185
7.6	Compare each group against the grand mean	185
7.6.1	Selecting a specific contrast	187
7.7	Compare adjacent means	188
7.7.1	Reverse adjacent contrasts	192
7.7.2	Selecting a specific contrast	193
7.8	Comparing the mean of subsequent or previous levels	194
7.8.1	Comparing the mean of previous levels	198
7.8.2	Selecting a specific contrast	199
7.9	Polynomial contrasts	200
7.10	Custom contrasts	202
7.11	Weighted contrasts	206
7.12	Pairwise comparisons	208

7.13	Interpreting confidence intervals	210
7.14	Testing categorical variables using regression	212
7.15	Summary	215
8	Categorical by categorical interactions	217
8.1	Chapter overview	217
8.2	Two by two models: Example 1	219
8.2.1	Simple effects	224
8.2.2	Estimating the size of the interaction	225
8.2.3	More about interaction	226
8.2.4	Summary	227
8.3	Two by three models	227
8.3.1	Example 2	227
8.3.2	Example 3	232
8.3.3	Summary	237
8.4	Three by three models: Example 4	237
8.4.1	Simple effects	240
8.4.2	Simple contrasts	240
8.4.3	Partial interaction	242
8.4.4	Interaction contrasts	243
8.4.5	Summary	245
8.5	Unbalanced designs	245
8.6	Main effects with interactions: anova versus regress	250
8.7	Interpreting confidence intervals	253
8.8	Summary	255
9	Categorical by categorical by categorical interactions	257
9.1	Chapter overview	257
9.2	Two by two by two models	258
9.2.1	Simple interactions by season	260
9.2.2	Simple interactions by depression status	261
9.2.3	Simple effects	263

9.3	Two by two by three models	263
9.3.1	Simple interactions by depression status	266
9.3.2	Simple partial interaction by depression status	266
9.3.3	Simple contrasts	268
9.3.4	Partial interactions	268
9.4	Three by three by three models and beyond	270
9.4.1	Partial interactions and interaction contrasts	272
9.4.2	Simple interactions	276
9.4.3	Simple effects and simple comparisons	279
9.5	Summary	280
III	Continuous and categorical predictors	281
10	Linear by categorical interactions	283
10.1	Chapter overview	283
10.2	Linear and two-level categorical: No interaction	283
10.2.1	Overview	283
10.2.2	Examples using the GSS	286
10.3	Linear by two-level categorical interactions	291
10.3.1	Overview	291
10.3.2	Examples using the GSS	294
10.4	Linear by three-level categorical interactions	299
10.4.1	Overview	299
10.4.2	Examples using the GSS	301
10.5	Summary	308
11	Polynomial by categorical interactions	311
11.1	Chapter overview	311
11.2	Quadratic by categorical interactions	311
11.2.1	Overview	312
11.2.2	Quadratic by two-level categorical	315
11.2.3	Quadratic by three-level categorical	323

11.3	Cubic by categorical interactions	329
11.4	Summary	334
12	Piecewise by categorical interactions	335
12.1	Chapter overview	335
12.2	One knot and one jump	338
12.2.1	Comparing slopes across gender	342
12.2.2	Comparing slopes across education	343
12.2.3	Difference in differences of slopes	343
12.2.4	Comparing changes in intercepts	344
12.2.5	Computing and comparing adjusted means	344
12.2.6	Graphing adjusted means	347
12.3	Two knots and two jumps	351
12.3.1	Comparing slopes across gender	356
12.3.2	Comparing slopes across education	357
12.3.3	Difference in differences of slopes	358
12.3.4	Comparing changes in intercepts by gender	359
12.3.5	Comparing changes in intercepts by education	360
12.3.6	Computing and comparing adjusted means	361
12.3.7	Graphing adjusted means	364
12.4	Comparing coding schemes	366
12.4.1	Coding scheme #1	367
12.4.2	Coding scheme #2	368
12.4.3	Coding scheme #3	370
12.4.4	Coding scheme #4	372
12.4.5	Choosing coding schemes	373
12.5	Summary	374
13	Continuous by continuous by categorical interactions	375
13.1	Chapter overview	375
13.2	Linear by linear by categorical interactions	376
13.2.1	Fitting separate models for males and females	376

13.2.2	Fitting a combined model for males and females	378
13.2.3	Interpreting the interaction focusing in the age slope	380
13.2.4	Interpreting the interaction focusing on the educ slope	382
13.2.5	Estimating and comparing adjusted means by gender	384
13.3	Linear by quadratic by categorical interactions	386
13.3.1	Fitting separate models for males and females	386
13.3.2	Fitting a common model for males and females	388
13.3.3	Interpreting the interaction	389
13.3.4	Estimating and comparing adjusted means by gender	390
13.4	Summary	392
14	Continuous by categorical by categorical interactions	393
14.1	Chapter overview	393
14.2	Simple effects of gender on the age slope	398
14.3	Simple effects of education on the age slope	399
14.4	Simple contrasts on education for the age slope	400
14.5	Partial interaction on education for the age slope	400
14.6	Summary	401
IV	Beyond ordinary linear regression	403
15	Multilevel models	405
15.1	Chapter overview	405
15.2	Example 1: Continuous by continuous interaction	406
15.3	Example 2: Continuous by categorical interaction	409
15.4	Example 3: Categorical by continuous interaction	413
15.5	Example 4: Categorical by categorical interaction	417
15.6	Summary	421
16	Time as a continuous predictor	423
16.1	Chapter overview	423
16.2	Example 1: Linear effect of time	424
16.3	Example 2: Linear effect of time by a categorical predictor	428

16.4	Example 3: Piecewise modeling of time	433
16.5	Example 4: Piecewise effects of time by a categorical predictor	438
16.5.1	Baseline slopes	443
16.5.2	Change in slopes: Treatment versus baseline	444
16.5.3	Jump at treatment	445
16.5.4	Comparisons among groups	446
16.6	Summary	448
17	Time as a categorical predictor	449
17.1	Chapter overview	449
17.2	Example 1: Time treated as a categorical variable	450
17.3	Example 2: Time (categorical) by two groups	455
17.4	Example 3: Time (categorical) by three groups	459
17.5	Comparing models with different residual covariance structures	464
17.6	Analyses with small samples	466
17.7	Summary	474
18	Nonlinear models	475
18.1	Chapter overview	475
18.2	Binary logistic regression	476
18.2.1	A logistic model with one categorical predictor	476
18.2.2	A logistic model with one continuous predictor	484
18.2.3	A logistic model with covariates	486
18.3	Multinomial logistic regression	491
18.4	Ordinal logistic regression	497
18.5	Poisson regression	500
18.6	More applications of nonlinear models	503
18.6.1	Categorical by categorical interaction	503
18.6.2	Categorical by continuous interaction	510
18.6.3	Piecewise modeling	516
18.7	Summary	522
19	Complex survey data	523

V Appendices	529
A Customizing output from estimation commands	531
A.1 Omission of output	531
A.2 Specifying the confidence level	533
A.3 Customizing the formatting of columns in the coefficient table	534
A.4 Customizing the display of factor variables	536
B The margins command	545
B.1 The predict() and expression() options	545
B.2 The at() option	548
B.3 Margins with factor variables	551
B.4 Margins with factor variables and the at() option	557
B.5 The dydx() and related options	559
B.6 Specifying the confidence level	563
B.7 Customizing column formatting	564
C The marginsplot command	567
D The contrast command	583
D.1 Inclusion and omission of output	584
D.2 Customizing the display of factor variables	586
D.3 Adjustments for multiple comparisons	588
D.4 Specifying the confidence level	588
D.5 Customizing column formatting	589
E The pwcompare command	591
References	597
Author index	601
Subject index	603
16.1 Summary: Categorical by continuous interaction: <i>age</i> by <i>education</i>	421
16.2 Time as a continuous variable: <i>time</i> by <i>leverage</i>	423
16.2.1 Chapter overview	423
16.2.2 Example 1: Linear effect of time	423
16.2.3 Example 2: Linear effect of time by education	424