

Contents

	List of tables	xv
	List of figures	xvii
	Preface	xxvii
	Acknowledgments	xxix
1	Introduction	1
1.1	Overview of the book	1
1.2	Getting the most out of this book	3
1.3	Downloading the example datasets and programs	4
1.4	The GSS dataset	4
1.4.1	Income	5
1.4.2	Age	6
1.4.3	Education	10
1.4.4	Gender	12
1.5	The pain datasets	12
1.6	The optimism datasets	12
1.7	The school datasets	13
1.8	The sleep datasets	13
I	Continuous predictors	15
2	Continuous predictors: Linear	17
2.1	Chapter overview	17
2.2	Simple linear regression	17
2.2.1	Computing predicted means using the margins command . .	20
2.2.2	Graphing predicted means using the marginsplot command	22
2.3	Multiple regression	25

2.3.1	Computing adjusted means using the margins command . . .	26
2.3.2	Some technical details about adjusted means	28
2.3.3	Graphing adjusted means using the marginsplot command .	29
2.4	Checking for nonlinearity graphically	30
2.4.1	Using scatterplots to check for nonlinearity	31
2.4.2	Checking for nonlinearity using residuals	31
2.4.3	Checking for nonlinearity using locally weighted smoother .	33
2.4.4	Graphing outcome mean at each level of predictor	34
2.4.5	Summary	37
2.5	Checking for nonlinearity analytically	37
2.5.1	Adding power terms	38
2.5.2	Using factor variables	39
2.6	Summary	43
3	Continuous predictors: Polynomials	45
3.1	Chapter overview	45
3.2	Quadratic (squared) terms	45
3.2.1	Overview	45
3.2.2	Examples	49
3.3	Cubic (third power) terms	55
3.3.1	Overview	55
3.3.2	Examples	56
3.4	Fractional polynomial regression	62
3.4.1	Overview	62
3.4.2	Example using fractional polynomial regression	66
3.5	Main effects with polynomial terms	75
3.6	Summary	77
4	Continuous predictors: Piecewise models	79
4.1	Chapter overview	79
4.2	Introduction to piecewise regression models	80
4.3	Piecewise with one known knot	82

4.3.1	Overview	82
4.3.2	Examples using the GSS	83
4.4	Piecewise with two known knots	91
4.4.1	Overview	91
4.4.2	Examples using the GSS	91
4.5	Piecewise with one knot and one jump	96
4.5.1	Overview	96
4.5.2	Examples using the GSS	97
4.6	Piecewise with two knots and two jumps	102
4.6.1	Overview	102
4.6.2	Examples using the GSS	102
4.7	Piecewise with an unknown knot	109
4.8	Piecewise model with multiple unknown knots	113
4.9	Piecewise models and the marginsplot command	120
4.10	Automating graphs of piecewise models	123
4.11	Summary	126
5	Continuous by continuous interactions	127
5.1	Chapter overview	127
5.2	Linear by linear interactions	127
5.2.1	Overview	127
5.2.2	Example using GSS data	132
5.2.3	Interpreting the interaction in terms of age	133
5.2.4	Interpreting the interaction in terms of education	135
5.2.5	Interpreting the interaction in terms of age slope	137
5.2.6	Interpreting the interaction in terms of the educ slope	138
5.3	Linear by quadratic interactions	140
5.3.1	Overview	140
5.3.2	Example using GSS data	143
5.4	Summary	148

6	Continuous by continuous by continuous interactions	149
6.1	Chapter overview	149
6.2	Overview	149
6.3	Examples using the GSS data	154
6.3.1	A model without a three-way interaction	154
6.3.2	A three-way interaction model	158
6.4	Summary	164
II	Categorical predictors	165
7	Categorical predictors	167
7.1	Chapter overview	167
7.2	Comparing two groups using a t test	168
7.3	More groups and more predictors	169
7.4	Overview of contrast operators	175
7.5	Compare each group against a reference group	176
7.5.1	Selecting a specific contrast	177
7.5.2	Selecting a different reference group	178
7.5.3	Selecting a contrast and reference group	179
7.6	Compare each group against the grand mean	179
7.6.1	Selecting a specific contrast	181
7.7	Compare adjacent means	182
7.7.1	Reverse adjacent contrasts	185
7.7.2	Selecting a specific contrast	186
7.8	Comparing the mean of subsequent or previous levels	187
7.8.1	Comparing the mean of previous levels	191
7.8.2	Selecting a specific contrast	192
7.9	Polynomial contrasts	193
7.10	Custom contrasts	195
7.11	Weighted contrasts	198
7.12	Pairwise comparisons	200

7.13	Interpreting confidence intervals	202
7.14	Testing categorical variables using regression	205
7.15	Summary	208
8	Categorical by categorical interactions	209
8.1	Chapter overview	209
8.2	Two by two models: Example 1	211
8.2.1	Simple effects	215
8.2.2	Estimating the size of the interaction	216
8.2.3	More about interaction	217
8.2.4	Summary	218
8.3	Two by three models	218
8.3.1	Example 2	218
8.3.2	Example 3	223
8.3.3	Summary	228
8.4	Three by three models: Example 4	228
8.4.1	Simple effects	230
8.4.2	Simple contrasts	231
8.4.3	Partial interaction	233
8.4.4	Interaction contrasts	234
8.4.5	Summary	236
8.5	Unbalanced designs	236
8.6	Main effects with interactions: anova versus regress	241
8.7	Interpreting confidence intervals	244
8.8	Summary	246
9	Categorical by categorical by categorical interactions	249
9.1	Chapter overview	249
9.2	Two by two by two models	250
9.2.1	Simple interactions by season	252
9.2.2	Simple interactions by depression status	253
9.2.3	Simple effects	255

9.3	Two by two by three models	255
9.3.1	Simple interactions by depression status	258
9.3.2	Simple partial interaction by depression status	258
9.3.3	Simple contrasts	260
9.3.4	Partial interactions	260
9.4	Three by three by three models and beyond	262
9.4.1	Partial interactions and interaction contrasts	264
9.4.2	Simple interactions	268
9.4.3	Simple effects and simple comparisons	271
9.5	Summary	272
III	Continuous and categorical predictors	273
10	Linear by categorical interactions	275
10.1	Chapter overview	275
10.2	Linear and two-level categorical: No interaction	275
10.2.1	Overview	275
10.2.2	Examples using the GSS	278
10.3	Linear by two-level categorical interactions	283
10.3.1	Overview	283
10.3.2	Examples using the GSS	285
10.4	Linear by three-level categorical interactions	290
10.4.1	Overview	290
10.4.2	Examples using the GSS	293
10.5	Summary	299
11	Polynomial by categorical interactions	301
11.1	Chapter overview	301
11.2	Quadratic by categorical interactions	301
11.2.1	Overview	302
11.2.2	Quadratic by two-level categorical	305
11.2.3	Quadratic by three-level categorical	312

11.3	Cubic by categorical interactions	318
11.4	Summary	323
12	Piecewise by categorical interactions	325
12.1	Chapter overview	325
12.2	One knot and one jump	328
12.2.1	Comparing slopes across gender	332
12.2.2	Comparing slopes across education	333
12.2.3	Difference in differences of slopes	333
12.2.4	Comparing changes in intercepts	334
12.2.5	Computing and comparing adjusted means	334
12.2.6	Graphing adjusted means	337
12.3	Two knots and two jumps	341
12.3.1	Comparing slopes across gender	346
12.3.2	Comparing slopes across education	347
12.3.3	Difference in differences of slopes	348
12.3.4	Comparing changes in intercepts by gender	349
12.3.5	Comparing changes in intercepts by education	350
12.3.6	Computing and comparing adjusted means	351
12.3.7	Graphing adjusted means	354
12.4	Comparing coding schemes	356
12.4.1	Coding scheme #1	356
12.4.2	Coding scheme #2	358
12.4.3	Coding scheme #3	360
12.4.4	Coding scheme #4	361
12.4.5	Choosing coding schemes	363
12.5	Summary	364
13	Continuous by continuous by categorical interactions	365
13.1	Chapter overview	365
13.2	Linear by linear by categorical interactions	366
13.2.1	Fitting separate models for males and females	366

13.2.2	Fitting a combined model for males and females	368
13.2.3	Interpreting the interaction focusing in the age slope	370
13.2.4	Interpreting the interaction focusing on the educ slope	372
13.2.5	Estimating and comparing adjusted means by gender	374
13.3	Linear by quadratic by categorical interactions	376
13.3.1	Fitting separate models for males and females	376
13.3.2	Fitting a common model for males and females	378
13.3.3	Interpreting the interaction	379
13.3.4	Estimating and comparing adjusted means by gender	380
13.4	Summary	382
14	Continuous by categorical by categorical interactions	383
14.1	Chapter overview	383
14.2	Simple effects of gender on the age slope	387
14.3	Simple effects of education on the age slope	388
14.4	Simple contrasts on education for the age slope	389
14.5	Partial interaction on education for the age slope	389
14.6	Summary	390
IV	Beyond ordinary linear regression	391
15	Multilevel models	393
15.1	Chapter overview	393
15.2	Example 1: Continuous by continuous interaction	394
15.3	Example 2: Continuous by categorical interaction	397
15.4	Example 3: Categorical by continuous interaction	401
15.5	Example 4: Categorical by categorical interaction	404
15.6	Summary	408
16	Time as a continuous predictor	411
16.1	Chapter overview	411
16.2	Example 1: Linear effect of time	412
16.3	Example 2: Linear effect of time by a categorical predictor	416

16.4	Example 3: Piecewise modeling of time	421
16.5	Example 4: Piecewise effects of time by a categorical predictor . . .	426
16.5.1	Baseline slopes	430
16.5.2	Change in slopes: Treatment versus baseline	431
16.5.3	Jump at treatment	432
16.5.4	Comparisons among groups	433
16.6	Summary	434
17	Time as a categorical predictor	437
17.1	Chapter overview	437
17.2	Example 1: Time treated as a categorical variable	438
17.3	Example 2: Time (categorical) by two groups	443
17.4	Example 3: Time (categorical) by three groups	447
17.5	Comparing models with different residual covariance structures . . .	452
17.6	Summary	454
18	Nonlinear models	455
18.1	Chapter overview	455
18.2	Binary logistic regression	456
18.2.1	A logistic model with one categorical predictor	456
18.2.2	A logistic model with one continuous predictor	463
18.2.3	A logistic model with covariates	465
18.3	Multinomial logistic regression	470
18.4	Ordinal logistic regression	475
18.5	Poisson regression	478
18.6	More applications of nonlinear models	481
18.6.1	Categorical by categorical interaction	481
18.6.2	Categorical by continuous interaction	487
18.6.3	Piecewise modeling	492
18.7	Summary	498
19	Complex survey data	499

V	Appendices	505
A	The margins command	507
A.1	The predict() and expression() options	507
A.2	The at() option	510
A.3	Margins with factor variables	513
A.4	Margins with factor variables and the at() option	517
A.5	The dydx() and related options	519
B	The marginsplot command	523
C	The contrast command	535
D	The pwcompare command	539
	References	545
	Author index	549
	Subject index	551