

## Index

- addition, in linear transformations, 101
- additive rules, of probability, 213–215
  - disjoint events, 213
  - First Additive Rule, 213–214
  - mutually exclusive events, 213
  - Second Additive Rule, 214–215
- adjusted *R* values, 464–465
- alternative hypotheses, 270
  - for one sample *t*-tests, 298
  - in one-way analysis of variance, 412
  - for paired samples, 319–320
  - t*-distribution and, 298
  - two sample designs, 309
  - in two-way analysis of variance, 412
- analysis of variance, 368, 369–380
  - assumptions of, 374–375
  - computations for, 372
  - development of, 369
  - effect size measurement, 380–384
  - F* distribution, 375–379
  - F*-ratios, 375
  - index of separation for, 371–372
  - Kruskal-Wallis analysis of variance, 565–567
  - Levene's test, 382–383
  - mean squares, 372
  - simple linear regression, 459–461
  - summary table, 380
  - in tests on means, 369–370
  - t*-tests, 370–371
  - variability between/within groups, 371
- ANOVA. *See* analysis of variance
- arithmetic mean, 70–74
  - of dichotomous variable, 72–73
  - median compared to, 74–76
  - mode compared to, 74–76
  - weighted, 73–74
- assumptions
  - of analysis of variance, 374–375
  - of chi-square test of independence, 550–552
  - correlation for, 307–315
  - of independent samples, 307–315
  - of one way analysis of variance, 374–375
  - of paired samples, 318–323
  - of regression analysis, 467–470
  - of two sample designs, 307–315
  - of two-way analysis of variance, 413–414
- asymmetric curves, in univariate distribution, 36
- average squared deviation, 186
- average treatment effect, 353
- balanced factorial designs, 414
- Bem-Sex-Role Inventory, 125
- best-fitting linear equations
  - average squared deviation in, 186
  - least squares criterion, 185
  - linear regression and, 183–190
  - Pearson Product Moment Correlation Coefficient and, 183
  - prediction lines, 185, 186
  - regression coefficients, 187
  - regression lines, 185, 186
  - residuals, 185
  - standard error of estimate in, 186
- $\beta$  coefficients
  - with correlated predictors, 494–496
  - in multiple linear regression, 493–496, 497
  - with non-correlated predictors, 493–496
- between group variances, 371, 372–373
- bias
  - populations and, 259–260
  - selection, 360
- bimodal distributions, 65–69
- binomial probability model, 223–232
  - applicability of, 228–232
  - cumulative values, 231
  - distribution in, 224–228
  - factorial notation, 227
  - identical trials, 223–224
  - independent trials, 223–224
  - Law of Large Numbers and, 230
  - normal probability model and, 238
- bivariate contingency table, 547
- bivariate normal distribution, 445–448
  - homoscedasticity property, 447
  - linearity property, 447
  - normality property, 447
  - Pearson Product Moment Correlation Coefficient and, 448–454
- blocking design, 352–353
  - average treatment effect, 353
  - causal inferences, 356
  - counterfactuals, 354–355
  - expected values, 355
  - true control groups, 353–356

- blocks
  - hierarchical analyses, 521
  - in research design, 353
- Bonferroni adjustments, 368, 394–398
  - on multiple measures, 396–398
  - planned comparisons, 395
- bootstrap technique, 323–327
  - b*-weight, 459
  - Central Limit Theorem, 323
  - confidence intervals, 325
  - development of, 324
  - estimates, 324
  - p*-values, 325
  - for regression coefficients, 459
  - resampling, 324
  - sampling, 324
  - standard error of mean, 324
  - t*-distribution, 323
  - t*-test, 325, 327
- box-and-whiskers plot, 44
- boxplots, 43–49, 78
  - in legacy dialogs, 49–48
  - linear transformations, 103–104
  - outliers and, 46
- b*-weight
  - bootstrap estimate, 459
  - with correlated predictors, 493–496
  - first-order effects, 521
  - interactions, 517–518
  - in multiple linear regression, 493–497, 505–507, 517–518
  - with non-correlated predictors, 494–496
  - as partial slope, 505–507
  - testing for statistical significance, 456–459, 501–502
  - t*-ratios, 501–502
- causal inferences, 356
- causal research studies, 348–351
  - construct measures, 346–347
  - observational studies and, 349–350
  - plausible alternative explanations for, 362–363
  - random assignments in, 350–351, 354
  - true experiments, 350–351
  - validity of, threats to, 361–363
  - weight of, 346–347
- causality
  - instrumental variables, 357–358
  - from observational data, 357–359
  - in Pearson Product Moment Correlation Coefficient, 153–154
  - propensity score matching, 357
  - RDD for, 358–359
- centered variables, 521
- centering, 521
- Central Limit Theorem (CLT)
  - bootstrap, 323
  - development of, 256
  - hypothesis testing and, 282
  - interval estimation, 266
  - parent populations and, 294, 296
  - probability and, 255–259
  - sampling distributions and, 255–259
  - sampling with replacement, 258
  - single sample designs, 290
- central tendency measures, 65
- chi-square distribution
  - cross-tabulation, 547, 548
  - data sets, 544, 550
  - degrees of freedom, 541–542, 545–546
  - goodness-of-fit test, 542–547
  - as nonparametric method, 540–552
  - p*-values, 543–544, 547
  - test of independence, 547–552
- chi-square test of independence, 547–552
  - assumptions of, 550–552
  - bivariate contingency table, 547
  - data sets, 550
  - p*-values, 547
- Classical Test Theory, 347
- CLT. *See* Central Limit Theorem
- clustered bar graphs, 169
- coefficients
  - bootstrap technique for, 459
  - partial regression, 496
  - Pearson Product Moment Correlation Coefficient, 150, 153–154, 155, 183, 190–191, 448–454
  - Phi Coefficient, 157, 162–167
  - Point Biserial Correlation Coefficient, 157–162, 315
  - population correlation coefficient, 451–454
  - regression, 187, 455
  - Spearman Rank Correlation Coefficient, 155–157, 558
- column main effect test, 412
- Complement Rule, 212
  - in normal probability model, 234
- computers, in data analysis, 1–2
- conditional probability, 218–219
- confidence intervals, of a population mean
  - bootstrap technique, 325
  - interval estimation, 267, 269–270
  - population correlation coefficient, 451–454
  - sampling, 269–270
  - single sample designs, 294–298, 301
  - of slope of regression equation, 459, 471, 473–474, 513
  - t*-test, 294–298, 305–315, 317–323
  - two sample designs, 305–307, 314–315
  - using independent samples, 305–307
  - using normal distribution, 267, 269–270
  - using paired samples, 317–323
  - using *t*-distribution, 294–298, 301, 328
- confounder variables, 350
- contingency tables, 165
- continuous variables, 8–11, 524–527
- Cook's influence values, 473–474
- corrected total SS scores, 421
- correlations. *See also* Spearman Rank Correlation Coefficient
  - best-fitting linear equations and, 183
  - bivariate normal distribution and, 448–454

## INDEX

597

- bivariate relationships, 167–170
- causation in, 153–154
- data reliability, 155
- dichotomous variables in, 157–167
- direct linear relationships, 147–148
- indirect linear relationships, 147–148
- interpretation of, 152–155
- linear regressions and, 190–191
- linear transformations and, 154
- matrices in, 150
- ordinal measurement levels in, 153
- perfect negative linear relationships, 149
- perfect positive linear relationships, 149
- Phi Coefficient and, 157, 162–167
- Point Biserial Correlation Coefficient, 157–162
- range restrictions, 154–155
- scatterplots and, 147
  - for selected variables, 153
  - shape of distributions, 155
  - strength of relationships, 152–153
  - zero value for, 448–451
- counterfactuals, 354–355
- criterion variables, 454
- crossed designs, 405
- crossed factorial designs, 405, 416
- cross-tabulation, 547, 548
- cumulative binomial probability value, 231
- cumulative percent distribution, 38
  
- Darwin, Charles, 147
- data analysis
  - computers in, 1–2
  - context setting in, 11–19
- data management, 126–130
- data reliability, 155
- data transformation, 46–47
- data value
  - hypothesis testing, 271
  - in univariate distributions, 20
- de Moivre, Abraham, 256
- degrees of freedom
  - chi-square distribution, 541–542, 545–546
  - independent data in, 292
  - for independent samples, 306
  - in nonparametric methods, 541–542, 545–546
  - in one-way analysis of variance, 372
  - for paired samples, 306
  - in regression analysis, 457
  - for single sample designs, 292–293
  - for *t*-distribution, 292–293
  - two-way analysis of variance, 415
- dependent samples, 304–305 *See also* paired samples
- dependent variables, 540, 558–567
- descriptive statistics, 2
  - defined, 210
- descriptive studies, 347–348
  - construct measures, 346–347
  - plausible alternative explanations for, 362–363
  - status quo in, 347
  - target populations, 347
  - validity of, threats to, 361–363
  - weight of, 346–347
- deviation, in regression equations, 472
- diagnostics, 474–477
- dialogs. *See* legacy dialogs
- dichotomous predictors, 478–479
- dichotomous variables, 72–73, 524–527
  - arithmetic mean of, 72–73
  - as independent, 196–199
  - interactions with, 524–527
  - in multiple linear regression, 508–514
- direct linear relationships, 147–148
- direction, in scatterplots, 142
- discrepancy, in regression equations, 472
  - Studentized residual value, 472–473
- discrete cases, 210–212
- discrete variables, 8–11
- disjoint events, 212
  - additive rules of probability, 213
- distribution. *See also* frequency distributions; percent distributions; *t*-distribution
  - in binomial probability model, 224–228
  - chi-square distributions, 540, 547–552
  - F distribution, 375–379
  - hypergeometric probability, 553, 554–558
  - joint, 445
  - linear transformations shaped by, 101–102
  - normal, 540
  - normal probability model and, 232–238
  - of parent populations, 293–294, 539
  - sampling, 250–255
  - Studentized range, 384
  - summary statistics of, 102–106
  - z*-Scores and, 112–114
- distribution-free methods, 539–540 *See also* chi-square distribution
  - dependent variable levels, 540
- distribution-tied methods, 539–540
- division, in linear transformations, 101
- The Doctrine of Chances* (de Moivre), 256
  
- effect sizes
  - analysis of variance, 380–384
  - Cohen's *d*, 199, 285
  - correlation and, 152
  - hypothesis testing and, 279–280, 284
  - independent samples *t*-test, 315–317
  - in linear regression, 199
  - for one sample *t*-test, 323
  - one-way analysis of variance, 380–384
  - for paired samples *t*-test, 323
  - partial eta squared, 423
  - t*-distribution test, 315–317, 323, 329
  - two-way analysis of variance, 422–426
  - variances and, 380–384
- Efron, Bradley, 324

- endogeneity, 357  
 equations. *See also* best-fitting linear equations; regression equations  
 $\beta$ , 493–496, 497  
 $b$ -weight, 493–496  
 independent variables, 503  
 standardized, 191, 510  
 for  $t$ -test values, 328  
 unstandardized, 510  
 estimators, 259–260  
 bootstrap technique, 324  
 unbiased, 259  
 variance, 260  
 expected values, 355  
 experimental mortality, 360  
 experiments  
 in probability, 210–212  
 true, 350–351  
*Exploratory Data Analysis* (Tukey), 48–49  
 external validity, for quasi-experimental design, 359, 361
- F distribution, 375–379  
 descriptive statistics, 378  
 Levene's test, 378  
 one-way analysis of variance, 375–379  
 two-way analysis of variance, 415–416
- factorial designs  
 balanced, 414  
 orthogonal, 405  
 for research, 353  
 in two-way analysis of variance, 405, 414  
 unbalanced, 414
- factorial notations, 227  
 family-wise error rates, 368  
 First Additive Rule of Probability, 213–214  
 first-order effects, 521  
 Fisher, R. A., 274–275, 369, 553  
 Fisher's Exact Test, 552–558  
 hypergeometric distribution, 554–558  
 $p$ -values, 554  
 five-number summaries, 43–49  
 fixed factors, 426  
 fixed-effects models, 426  
 $F$ -ratios, 375  
 two-way analysis of variance, 415–416
- frequency distributions  
 bar graphs, 21–23  
 boxplots, 43–49  
 five-number summaries, 43–49  
 graphical selection summary, 49  
 grouped, 26  
 histograms, 30–33  
 interval level measurements, 25–27  
 IQR for, 43  
 line graphs, 33–35  
 ogive curves, 38–39  
 ordinal level measurements, 25–27  
 percentile ranks, 39–40  
 percentiles, 40–43
- pie graphs, 23–25  
 ratio level measurements, 25–27  
 relative frequency, 21  
 S curves, 38–39  
 skewness of, 36  
 stem-and-leaf displays and, 27–30  
 tables, 20–21  
 ungrouped, 27  
 in univariate distributions, 20
- Galton, Francis, 147  
 Gauss, Johann Friedrich Carl, 232  
 global hypothesis, 394  
 goodness-of-fit  
 chi-square distribution and, 542–547  
 leverage and, 470–472  
 of regression equations, 465–477  
 residual plots, 467–470  
 Gossett, William Sealy, 291  
 grand means, 406  
 score deviations, 420–421  
 graphical selection summary, 49  
 grouped frequency distribution, 26
- Handbook of Experimental Psychology*, 3–4  
 hierarchical analysis, 521  
 hierarchical multiple regression approach, 518–519  
 histograms, 30–33  
 homoscedasticity, 447  
 Honestly Significant Difference (HSD), 384–385  
 Studentized range distribution, 384  
 Studentized range statistics, 384  
 hypergeometric distribution, 554–558  
 hypothesis of no effect, 271  
 hypothesis testing, 270–278 *See also* alternative hypotheses;  
 null hypotheses  
 Central Limit Theorem and, 282  
 data input and, 271  
 effect size and, 279–280, 284  
 global, 394  
 interval estimation and, 278–279  
 non-directional, 301  
 one-tailed tests, 276  
 outcome likelihood, 271  
 parent populations, 298–300  
 power concept and, 280–285  
 $p$ -values, 271, 273  
 significance levels, 273–274, 284  
 standard error of mean and, 284–285  
 $t$ -distribution, 298–300  
 two-tailed tests, 276  
 type I errors, 281  
 type II errors, 280–285  
 $z$ -test, 273
- identical trials, in binomial probability model, 223–224  
 IDF. *See* inverse density function  
 independence, 218 *See also* chi-square test of independence  
 independent samples, 304–305

## INDEX

599

- assumptions of, 307–315
- confidence intervals, 305–307, 314–315
- degrees of freedom, 306
- effect size for, 315–317
- p*-values, 311
- skewness ratio, 307, 310
- standard error of mean differences, 306
- t*-distribution, 305–315
- independent trials, in binomial probability model, 223–224
- independent variables, 183
  - dichotomous, 196–199
  - in equations, 503
  - interactions with, 524–527
  - in multiple linear regression, 503, 508–514
- index of separation, 371–372
- indirect linear relationships, 147–148
- inferential statistics, 2 *See also* sampling
  - defined, 210
- infinite populations, 249
- influential observations, 471
  - Cook's influence values, 473–474
- instrumental variables, 357–358
- instrumentation, in quasi-experimental designs, 360
- interactions
  - b*-weight in, 517–518
  - dichotomous independent variables, 479, 524–527
  - disordinal, 408
  - hierarchical multiple regression approach, 518–519
  - as joint effect, 421–422
  - line graphs and, 410–411
  - in multiple regression, 515
  - ordinal, 408–410
  - as partialled product, 517, 525
  - with scale variables, 8–11, 514–515
  - statistical significance of, 510, 516–521, 527
  - two-way, 515, 521–524
  - in two-way analysis of variance, 407–411, 421–422, 524–527
- internal validity, for quasi-experimental design, 359, 360
- interquartile range (IQR), 43, 79–80
  - linear transformations, 104
- interval estimation, 264, 265, 266–269
  - Central Limit Theorem, 266
  - confidence intervals of a population mean of the slope of the regression equation, 459, 471, 473–474, 513
  - confidence intervals of a population mean using independent samples, 305–307
  - confidence intervals of a population mean using normal distribution, 267, 269–270
  - confidence intervals of a population mean using paired samples, 317–323
  - confidence intervals of a population mean using *t*-distribution, 294–298, 301, 328
  - hypothesis testing and, 278–279
- interval measurement levels, 5
  - histograms, 30–33
  - line graphs, 33–35
  - for percent distributions, 25–27
  - stem-and-leaf displays, 27–30
  - for temperature, 8
  - for univariate distributions, 25–35
- interval-leveled variables, 514–515 *See also* least interval-leveled variables
  - interactions, 514–515
- inverse density function (IDF), 237
- IQR. *See* interquartile range
- joint distribution, 445
- Kruskal-Wallis analysis of variance, 565–567
- Law of Large Numbers, 220
  - binomial probability model and, 230
- Least Significant Difference (LSD), 385–388
- least squares criterion, 185
- legacy dialogs, 49–48
- Levene's test, 307, 308, 312
  - F distribution, 378
  - one-way analysis of variance, 382–383
  - two-way analysis of variance, 424
  - variances, 382–383
- leverage, in regression equations, 470–472
- Likert scale, 10
  - recoding variables, 124
- line graphs
  - frequency distribution, 33–35
  - interaction effects, 410–411
- linear regression. *See also* multiple linear regression
  - best-fitting linear equations and, 183–190
  - criterion variables, 454
  - dependent variables and, 183
  - effect sizes in, 199
  - independent variables and, 183, 196–199
  - Pearson Product Moment Correlation Coefficient and, 190–191
  - population standard error of prediction, 455–456
  - prediction accuracy with, 190–191
  - for predictions, 454–463
  - predictors and, 183
  - regression equations, 183
  - scatterplots with, 199–201
  - standardized equations, 191
  - value of *R* in, 191–195
- linear transformations, 100–115
  - addition in, 101
  - boxplots, 103–104
  - comparability of measures, 100
  - defined, 99
  - distribution shaped by, 101–102
  - division in, 101
  - IQR, 104
  - multiplication in, 101
  - Pearson Product Moment Correlation Coefficient and, 154
  - reflection in, 107
  - subtraction in, 101
  - summary statistics and, 102–106
  - translation in, 106–107
- linearity, 447

- location characteristics, of univariate distributions, 65–76
  - applications for, 86–90
  - arithmetic mean as, 70–74
  - central tendency measures, 65
  - measure selection of, 86
  - median as, 69–70
  - modes, 65–69
- logarithms, 116–118
- longitudinal design, 318
- LSD. *See* Least Significant Difference
- macro programs, 253
- Mann, Henry B., 558
- Mann-Whitney *U* Test, 561–565
  - null hypothesis, 561, 564–565
  - U* values, 563–565
- matrices, 150
- means. *See also* arithmetic mean
  - grand, 406, 420–421
  - in one way analysis of variance, 369–370
  - row marginal, 406
  - sampling distribution of, 251–254
  - standard error of mean, 255, 284–285
  - in standard score systems, 108
  - in two-way analysis of variance, 406
  - weighted, 73–74
- measurement levels. *See also* interval measurement levels;
  - nominal measurement level; ordinal measurement levels;
  - ratio measurement levels
 Likert scale, 10, 124  
 for regression equations, 462  
 scales of, 6–8, 10
- measurement of variables, 3–8
  - data transformation, 46–47
  - location in, 86
  - spread in, 86
- median
  - arithmetic mean compared to, 74–76
  - mode mean compared to, 74–76
  - univariate distribution, 69–70
- median splits, 125
- metrics, 99
- midspread. *See* interquartile range
- mixed-effects models, 426
- moderator variables, 515
- modes
  - arithmetic mean compared to, 74–76
  - bimodal, 66–67
  - median compared to, 74–76
  - trimodal, 67
  - in univariate distributions, 65–69
- monotonic transformations. *See also* linear transformations;
  - nonlinear transformations
 defined, 99
- multiple correlations, 492
- multiple linear regression, 454
  - $\beta$  equations, 493–496, 497
  - b*-weight, 493–497, 505–507, 517–518
  - dichotomous variables in, 508–514
  - expansion of, 496–501
  - independent variables, 503, 508–514
  - linear composite of *X* variables, 492
  - model summary of, 509
  - R* values, 493–496
  - redundancy and, 491
  - summary of, 496–501
  - syntax files, 513–514
  - with two predictors, 492–493
  - zero-order correlations, 493
- multiple *t*-tests, 367–368
- multiplication, in linear transformations, 101
- Multiplicative Rule of Probability, 215–217
  - mutually exclusive events, 218
  - sampling with replacement in, 216
- mutually exclusive events
  - additive rules of probability, 212
  - independence and, 218
  - Multiplicative Rule of Probability, 218
- Neyman, Jerzy, 274–275
- noise components, 304
- nominal measurement level, 3–8
  - in univariate distribution, 20–25
- non-directional hypothesis testing, 301
- nonlinear transformations, 115–124
  - defined, 116
  - logarithms and, 116–118
  - ranking variables in, 123–124
  - square roots and, 118–123
- nonparametric methods
  - chi-square distribution, 540–552
  - cross-tabulation, 547, 548
  - data sets, 544, 550
  - degrees of freedom, 541–542, 545–546
  - with dependent variables, 540, 558–567
  - Fisher's Exact Test, 552–558
  - goodness-of-fit test, 542–547
  - Kruskal-Wallis analysis of variance, 565–567
  - Mann-Whitney *U* Test, 561–565
  - ordinal-leveled variables, 558–567
  - parametric compared to, 539–540
  - p*-values, 543–544, 547
  - Spearman Rank Correlation Coefficient, 558
  - Wilcoxon Sign Test, 558–561
- non-randomized controlled studies, 351–352
  - plausible alternative explanations for, 362–363
  - Simpson's Paradox, 352
- normal probability model, 232–238
  - binomial probability model and, 238
  - Complement Rule, 234
  - distribution and, 232–238
  - IDF and, 237
  - purpose of, 233
  - scores for, 233–234
  - z*-Scores, 236
- normality, 447
- null hypotheses, 270
  - for analysis of variance, 370–371
  - development of, 274–275
  - Mann-Whitney *U* Test, 561, 564–565

## INDEX

601

- one sample *t*-tests, 370–371
  - for paired samples, 319–320
  - rejection of, 274
  - t*-distribution and, 298
  - two sample designs, 307, 309
  - in two-way analysis of variance, 412
  - Wilcoxon Sign Test, 558–559
- numeric systems. *See* metrics; transformation, of numeric systems
- observational data, 357–359
- observational studies, 349–350
  - causality from, 357–359
  - endogeneity in, 357
  - instrumental variables in, 357–358
  - plausible alternative explanations in, 362–363
  - propensity score matching, 357
  - RDD for, 358–359
  - validity of, threats to, 361–363
- ogive curves, 38–39
- one-tailed tests, 276, 299
- one-way analysis of variance (ANOVA), 368, 369–380 *See also* post-HOC multiple comparison tests
  - assumptions of, 374–375
  - computations for, 372
  - development of, 369
  - effect size measurement, 380–384
  - F distribution, 375–379
  - F*-ratios, 375
  - index of separation for, 371–372
  - Levene's test, 378, 382–383
  - mean squares, 372
  - summary table, 380
  - in tests on means, 369–370
  - t*-tests, 370–371
  - variability between/within groups, 371
- ordinal interactions, 408–410
- ordinal measurement levels, 4–5
  - histograms, 30–33
  - in Pearson Product Moment Correlation Coefficient, 153
  - for percent distributions, 25–27
  - in Spearman Rank Correlation Coefficient, 155–157
  - stem-and-leaf displays, 27–30
  - for univariate distributions, 25–35
- orthogonal factorial designs, 405
- outliers, 36
  - boxplots and, 46
  - through *z*-Scores, 111–112
- paired samples, 304–305
  - alternative hypothesis for, 319–320
  - assumptions of, 318–323
  - confidence intervals, 317–323
  - dependent structure, 318
  - effect sizes for, 323
  - longitudinal design, 318
  - null hypothesis for, 319–320
  - repeated measures design, 318
  - skewness ratio for, 320
  - t*-test, 317–323
- pairs of values, 445
- panel design, 354
- parameters
  - common symbols for, 246–245
  - for populations, 245
- parametric methods, 539–540
- parent populations, 292
  - Central Limit Theorem and, 294, 296
  - hypothesis testing, 298–300
  - normal distribution of, 293–294
- partial eta squared effect size, 423
- partial regression coefficients, 496
- partial slopes, 505–507
- partialled product, 517, 525
- Pearson, Egon, 274–275
- Pearson, Karl, 147, 274–275, 543
- Pearson Product Moment Correlation Coefficient, 147–155
  - best-fitting linear equations and, 183
  - bivariate normal distribution and, 448–454
  - bivariate relationships, 167–170
  - causation in, 153–154
  - data reliability, 155
  - dichotomous variables in, 157–167
  - direct linear relationships, 147–148
  - indirect linear relationships, 147–148
  - interpretation of, 152–155
  - linear regressions and, 190–191
  - linear transformations and, 154
  - matrices in, 150
  - ordinal measurement levels in, 153
  - perfect negative linear relationships, 149
  - perfect positive linear relationships, 149
  - Phi Coefficient and, 157, 162–167
  - Point Biserial Correlation Coefficient and, 157–162
  - range restrictions, 154–155
  - scatterplots and, 147
    - for selected variables, 153
  - shape of distributions, 155
  - Spearman Rank Correlation Coefficient and, 155–157
  - strength of relationships, 152–153
  - zero value for, 448–451
- percent distributions
  - bar graphs, 21–23
  - boxplots, 43–49
  - cumulative, 38
  - five-number summaries, 43–49
  - graphical selection summary, 49
  - interval level of measurements, 25–27
  - IQR for, 43
  - ogive curves, 38–39
  - ordinal level of measurements, 25–27
  - percentile ranks, 39–40
  - percentiles, 40–43
  - pie graphs, 23–25
  - ratio level of measurements, 25–27
  - S curves, 38–39
  - skewness of, 36
  - tables, 20–21
  - in univariate distributions, 20–21

- percentile ranks
  - in distributions, 39–40
  - z-Scores and, 115
- percentiles, 40–43
- per-comparison error rates, 368
- perfect linear relationships, 149
- Phi Coefficient, 157, 162–167
  - contingency tables, 165
  - marginal counts, 164
- Point Biserial Correlation Coefficient, 157–162, 315
- point estimation, 264–265
- polygon. *See* line graphs
- population correlation coefficient, 451–454
- population mean estimation, 264–265
- population standard deviation, 264–265
- population standard error of prediction, 455–456
- populations
  - bias and, 259–260
  - estimators for, 259–260
  - in inferential statistics, 210
  - infinite, 249
  - parameters for, 245
  - parent, 292, 293–294, 296, 298–300
  - samples and, 245–246
  - in statistics, 2
  - target, 347
- post-HOC multiple comparison tests, 384–394
  - HSD, 384–385
  - LSD, 385–388
  - two-way analysis of variance, 426–432
- power, in hypothesis testing, 280–285
- prediction lines, 185, 186
- prediction models, 478
- predictions
  - accuracy of, with linear regressions, 190–191
  - population standard error estimation, 455–456
  - simple linear regression for, 454–463
  - standard error of prediction, 455
- predictors
  - $\beta$  equations, 493–496
  - b*-weight with, 493–496
  - dichotomous, 478–479
  - linear regressions and, 183
  - multiple linear regression with, 492–493
  - R*-values, 493–496
  - variables, 454
- pretest-posttest design, 354
- probability. *See also* binomial probability model; normal
  - probability model; theoretical probability models
    - additive rules of, 213–215
    - Central Limit Theorem and, 255–259
    - Complement Rule, 212
    - conditional, 218–219
    - discrete case, 210–212
    - disjoint events, 212, 213
    - experiments in, 210–212
    - independence and, 218
    - Law of Large Numbers, 220
    - Multiplicative Rule of, 215–217, 218
    - mutually exclusive events, 212, 218
    - sampling, 246–247
      - sampling with and without replacement, 249–250
  - probability sampling, 246–247
  - propensity score matching, 357
  - p*-values, 271, 273
    - bootstrap technique, 325
    - chi-square distribution, 543–544
    - chi-square test of independence, 547
    - Fisher's Exact Test, 554
    - in *t*-distribution, 298, 299
- quasi-experimental designs, 359–361
  - experimental mortality, 360
  - external validity of, threats to, 359, 361
  - history in, 360
  - instrumentation in, 360
  - internal validity of, threats to, 359, 360
  - maturation factors in, 360
  - selection bias in, 360
  - statistical regression, 360
  - testing by treatment interaction, 361
  - testing in, 360
- r* values, 199
- R* values
  - adjusted, 464–465
  - with correlated predictors, 494–496
  - effect size and, 199
  - estimation of, 464–465
  - in linear regressions, 191–195
  - in multiple linear regression, 493–496
  - with non-correlated predictors, 493–496
  - regression equations, 462
  - squared part correlations, 504
  - statistical significance of, 504–505
  - statistical testing for, 463–464
- random assignments, in causal studies, 350–351, 354
- random factors, 426
- random sampling, 246–248 *See also* sampling with
  - replacement; sampling without replacement
  - selection of, 247–248
- random-effects models, 426
- randomized blocking design, 352–353
  - average treatment effect, 353
  - causal inferences, 356
  - counterfactuals, 354–355
  - expected values, 355
  - true control groups, 353–356
  - two-way analysis of variance, 405
- range
  - in Pearson Product Moment Correlation Coefficient, 154–155
  - of univariate distributions, 79–80
- ratio measurement levels, 5–6
  - histograms, 30–33
  - line graphs, 33–35
  - for percent distributions, 25–27
  - stem-and-leaf displays, 27–30



## INDEX

603

- for univariate distributions, 25–35
- raw total SS scores, 421
- RDD. *See* regression discontinuity designs
- real data, context setting with, 11–19
- recoding variables, 124–126
  - Likert scale and, 124
- rectangular distributions, 67
- redundancy, 491
- reflection, 107
- regression coefficients, 187, 455
- regression discontinuity designs (RDD), 358–359
- regression equations, 183 *See also* best-fitting linear equations
  - assumptions of, 467–470
  - deviation in, 472
  - dichotomous predictors and, 478–479
  - discrepancy in, 472–473
  - goodness-of-fit, 465–477
  - influential observations, 471, 473–474
  - leverage in, 470–472
  - measuring fit for, 462
  - R values, 462
  - residual plots, 467–470
  - residuals in, 472
  - standard error of estimate, 462
  - standardized, 191, 510
  - unstandardized, 510
- regression lines, 185, 186
- regressors. *See* predictors
- related samples, 304–305
- relational studies, 348
  - construct measures, 346–347
  - inferences in, 348
  - plausible alternative explanations in, 362–363
  - validity of, threats to, 361–363
  - weight of, 346–347
- relative frequency distributions, 21
- reliability
  - for data, 155
  - for measures of weight, 346–347
- repeated measures design, 305
  - blocking design, 354
  - paired samples, 318
- resampling, 324
- research design. *See also* causal research studies; descriptive studies; quasi-experimental designs; relational studies; single sample designs; two sample designs
  - average treatment effect, 353
  - blocking, 352–353
  - blocks in, 353
  - causal inferences, 356
  - counterfactuals, 354–355
  - expected values, 355
  - factorial design, 353
  - for non-randomized controlled studies, 351–352
  - for observational studies, 349–350
  - RDD, 358–359
  - true control groups, 353–356
- residual plots, 467–470
  - goodness-of-fit, 467–470
- residual variances, 371
- residuals
  - best-fitting linear equations, 185
  - in regression equations, 472
  - sum of squares due to, 460
  - variances for, 371
- resistance statistics, 79
- row main effect test, 412
- row marginal means, 406–407
- S curves, 38–39
- sampling
  - bootstrap technique, 324
  - confidence intervals, 269–270
  - infinite populations, 249
  - in Multiplicative Rule of Probability, 216
  - populations and, 245–246
  - probability, 246–247
  - random, 246–248, 249–250
  - selection of, 247–248
  - in statistics, 2, 245
- sampling distributions, 250–255
  - Central Limit Theorem, 255–259
  - empirical means, 251–254
  - macro programs, 253
  - syntax file, 253
- sampling with replacement, 249–250
  - Central Limit Theorem, 258
  - in Multiplicative Rule of Probability, 216
  - probability and, 249–250
- sampling without replacement, 249–250
- scales of measurement, 6–8
  - hierarchy of, 6–7
  - Likert scale, 10, 124
- scatterplots
  - direction in, 142
  - in least interval-leveled variables, 139–147
  - with linear regressions, 199–201
  - Pearson Product Moment Correlation Coefficient and, 147
  - shape in, 142
  - strength in, 142
- score deviations, 420–421
- scores. *See also* standard score systems; z-Scores
  - corrected total SS, 421
  - modeling, 421
  - for normal probability model, 233–234
  - raw total SS, 421
  - in two-way analysis of variance, 421
- Second Additive Rule of Probability, 214–215
- selection, of samples, 247–248
  - independent and equal, 247
- selection bias, 360
- semi-partial correlations, 495
- shape
  - in Pearson Product Moment Correlation Coefficient distributions, 155
  - in scatterplots, 142
- significance levels, 273–274
  - hypothesis testing, 273, 284

- simple effects, 428
- simple linear regressions, 454–463
  - analysis of variance and, 459–461
  - sum of squares due to regression, 460
  - sum of squares due to residuals, 460
  - total sum of squares, 460
- simple random samples. *See* random sampling
- Simpson's Paradox, 352
- single components, 304
- single sample designs, 290–291
  - alternative hypotheses and, 298
  - Central Limit Theorem for, 300
  - confidence intervals for, 294–298, 301
  - degrees of freedom for, 292–293
  - effect size for, 300–303
  - hypothesis tests, 298–300
  - non-directional hypothesis testing, 301
  - null hypothesis and, 298
  - parent populations, 292, 293–294, 296, 298–300
  - $p$ -values in, 298, 299
  - skewness ratio, 296–297
  - $t$ -distribution, 291–303
  - $z$ -statistics, 291
- skewness, 36
  - in analysis of variance, 379
  - independent samples, 307, 310
  - in one samples, 320
  - in paired samples, 320
  - $t$ -distribution, 296–297
  - of univariate distributions, 84–85, 89–90
- Spearman Rank Correlation Coefficient, 155–157
  - as nonparametric method, 558
- spread, as measurement criteria, 86
- spread, of univariate distributions, 76–84
  - applications for, 86–90
  - boxplots, 78
  - IQR for, 79–80
  - measure selection of, 86
  - range of, 79–80
  - standard deviation, 83–84
  - variance in, 80–83
- square roots, nonlinear transformations and, 116–118
- squared part correlations, 504
- standard deviation, of univariate distributions, 83–84
- standard error of estimate, 186, 455
  - regression equations, 462
- standard error of mean, 255
  - bootstrap technique, 324
  - hypothesis testing and, 284–285
  - independent samples, 306
- standard error of prediction, 455
- standard score systems
  - in linear transformation, 107–115
  - means and standard deviations in, 108
  - $z$ -Scores, 109–115
- standardized regression equations, 191, 510
- statistical regression, 360
- statistical significance
  - $b$ -weight for, 456–459, 501–502, 504
  - of effect size, 279–280
  - for  $F$ -test, 381
  - hierarchical multiple regression approach, 518–519
  - of interactions, 516–521, 527
  - of  $p$ -values, 311
  - of  $R$  values, 463–464, 504–505
  - of regression equations, 510
  - of two-way interactions, 521–524
  - of  $z$ -values, 561
- statistics. *See also* inferential statistics
  - common symbols for, 246–245
  - descriptive, 2, 210, 378
  - populations in, 2
  - purpose of, 1
  - samples, 2, 245
  - summary, 102–106
- status quo, 347
- stem-and-leaf displays, frequency distribution, 27–30
- strength
  - in Pearson Product Moment Correlation Coefficient, 152–153
  - in scatterplots, 142
- Studentized range distribution, 384
- Studentized range statistics, 384
- Studentized residual value, 472–473
- studies. *See* causal research studies; descriptive studies; observational studies; relational studies
- subtraction, in linear transformations, 101
- sum of squares due to regression, 460
- sum of squares due to residuals, 460
- summary statistics, 102–106
- symmetric curves, in univariate distribution, 36
- syntax files
  - in data management, 126–130
  - multiple linear regression, 513–514
  - sampling distributions, 253
- target populations, 347
- $t$ -distribution
  - alternative hypotheses and, 298
  - bootstrap, 323
  - Central Limit Theorem, 300
  - confidence intervals for, 294–298, 301, 328
  - degrees of freedom for, 292–293
  - effect size for, 300–303
  - hypothesis tests, 298–300
  - independent samples, 305–315
  - non-directional hypothesis testing, 301
  - null hypothesis and, 298
  - one samples, 305–315
  - paired samples, 305–315
  - parent populations, 292, 293–294, 296, 298–300
  - $p$ -values in, 298, 299
  - single sample designs, 291–303
  - skewness ratio, 296–297
  - $z$ -statistics, 291
- testing. *See also* post-HOC multiple comparison tests
  - in quasi-experimental designs, 360
  - for  $R$  values, 463–464

## INDEX

605

- by treatment interaction, 361
- theoretical probability models. *See also* binomial probability model
  - advantages of, 223
- total sum of squares, 414–415, 460
- transformation, of numeric systems. *See also* linear transformations; nonlinear transformations
  - combining variables in, 126
  - defined, 99
  - monotonic, 99
  - recoding variables in, 124–126
- translation, in linear transformations, 106–107
  - centering, 106–107
- t*-ratios, 501–502
- trimodal distributions, 67
- true control groups, 353–356
- true experiments, in causal studies, 350–351
  - confounder variables, 350
- t*-statistic, 307
- t*-test, 307
  - analysis of variance, 370–371
  - bootstrap technique, 325, 327
  - confidence intervals, 317–323
  - effect size for, 315–317, 323, 329
  - equations for, 328
  - independent samples, 317–323
  - multiple, 367–368
  - one sample, 317–323
  - paired samples, 317–323
  - Point Biserial Correlation Coefficient, 315
  - robustness of, 307
  - type I errors, 368
- Tukey, John, 48–49
- two sample designs, 303–317
  - alternative hypotheses for, 309
  - assumptions of, 307–315
  - confidence intervals, 305–307, 314–315
  - degrees of freedom for, 306
  - dependent samples, 304–305
  - effect size for, 315–317
  - independent samples, 304–305
  - Levene's test, 307, 308, 312
  - noise components in, 304
  - null hypothesis, 307, 309
  - one samples, 304–305
  - p*-values, 311
  - repeated-measures design, 305
  - signal components in, 304
  - skewness ratio, 307, 310
  - standard error of mean differences, 306
  - t*-distribution, 305–315
- two-factor designs, 404–407
- two-tailed tests, 276
- two-way analysis of variance
  - alternative hypothesis in, 412
  - assumptions of, 413–414
  - column main effect test, 412
  - computations by hand, 416–420
  - corrected total SS, 421
  - crossed designs, 405
  - crossed factorial designs, 405, 416
  - degrees of freedom, 415
  - effect size, 422–426
  - factorial designs, 405, 414
  - fixed factors, 426
  - F*-ratios, 415–416
  - grand mean, 406, 420–421
  - interactions in, 407–411, 421–422
  - joint effects, 421–422
  - Levene's test, 378, 424
  - mixed-effects models, 426
  - modeling scores, 421
  - null hypothesis in, 412
  - partitioning total sum of squares, 414–415
  - post-HOC multiple comparison tests, 426–432
  - random factors, 426
  - randomized block designs, 405
  - raw total SS, 421
  - row main effect test, 412
  - row marginal means, 406–407
  - score deviation decompositions, 420–421
  - simple effects, 428
  - summary of, 432–437
  - two-factor design, 404–407
- two-way interactions, 521–524
- type I errors, 281
  - t*-tests, 368
- type II errors, 280–285
- U* values, 563–565
- unbalanced factorial designs, 414
- unbiased estimators, 259
- ungrouped frequency distribution, 27
- uniform univariate distributions, 67
- univariate distributions. *See also* location characteristics, of univariate distributions; spread, of univariate distributions
  - asymmetric curves, 36
  - bimodal, 65–69
  - boxplots, 43–49, 78
  - data accumulation, 38–43
  - data value occurrences, 20
  - five-number summaries, 43–49
  - frequency distributions, 20
  - graphical selection summary, 49
  - interval level measurements, 25–35
  - IQR for, 43, 79–80
  - median, 69–70
  - mode in, 65–69
  - nominal level measurements, 20–25
  - ordinal level measurements, 25–35
  - outliers, 36
  - percent distributions, 20–21
  - percentile ranks, 39–40
  - percentiles, 40–43
  - range of, 79–80
  - ratio level measurements, 25–35
  - rectangular, 67

- univariate distributions (*cont.*)
  - resistance statistics, 79
  - shape of, 36–38
  - skewness of, 84–85, 89–90
  - standard deviation of, 83–84
  - symmetric curves, 36
  - of temperature, 77
  - trimodal, 67
  - uniform, 67
  - variance in, 80–83
- unrelated samples, 304–305
- unstandardized regression equations, 510
- validity
  - external, for quasi-experimental design, 359
  - internal, for quasi-experimental design, 359, 360
  - for measures of weight, 346–347
- values
  - cumulative binomial probability, 231
  - data, 20
  - data value occurrences, 20
  - expected, 355
  - r* values, 199
  - R* values, 191–195, 199
- variables, 3–8 *See also* least interval-leveled variables
  - centered, 521
  - combination of, in numeric systems, 126
  - confounder, 350
  - continuous, 8–11, 524–527
  - criterion, 454
  - dependent, 540, 558–567
  - dichotomous, 72–73, 196–199, 524–527
  - direct linear relationship, 147–148
  - discrete, 8–11
  - indirect linear relationship, 147–148
  - instrumental, 357–358
  - interactions between, 514–515
  - interval-leveled, 514–515
  - least interval-leveled, 138–155
  - linear regressions and, 183, 196–199
  - measurement of, 3–8, 46–47, 86
  - median split, 125
  - as moderators, 515
  - nominal-leveled, 9, 22, 66, 169, 410–411, 539, 540
  - ordinal-leveled, 558–567
  - Pearson Product Moment Correlation Coefficient for, 153
  - predictor, 454
  - ranking of, in nonlinear transformations, 123–124
  - recoding, 124–126
  - variance estimators, 260
  - variances, 80–83 *See also* one-way analysis of variance; two-way analysis of variance
    - Bonferroni adjustments, 368, 394–398
    - effect size measurement, 380–384
    - global hypothesis test, 394
    - between groups, 371, 372–373
    - within groups, 371, 373–374
    - Levene's test, 382–383
    - residual, 371
  - weighted mean, 73–74
  - Whitney, D. Ransom, 558
  - Wilcoxon, Frank, 558
  - Wilcoxon Sign Test, 558–561
    - null hypothesis, 558–559
    - z*-values, 561
  - within group variances, 371, 373–374
- zero-order correlations, 493
- z*-scores, 109–115
  - conversion of, 110–111
  - normal probability models, 236
  - outliers through, 111–112
  - percentile ranks and, 115
  - for scores in different distributions, 112–114
- z*-statistics, 291
- z*-test, 273
- z*-values, 561