

Test: the match tests.

Decision rules: (1) at $\alpha=5\%$, reject H_0 in favour of H_1 if $L_1 \geq 14$,
 (2) at $\alpha=5\%$, reject H_0 in favour of H_1 if $L_2 \geq 18$.

$L_1=16$, which is significant at $\alpha=1\%$, while $L_2=18$, which is only significant at $\alpha=5\%$.

(ii)

H_0 : The average amount of food eaten is the same for all deprivation levels.

H_1 : At least one average amount is different from the rest.

Test: the match tests.

Decision rules: (1) at $\alpha=5\%$, reject H_0 in favour of H_1 if $L_1 \geq 14$,
 (2) at $\alpha=5\%$, reject H_0 in favour of H_1 if $L_2 \geq 18$.

$L_1=16$ and $L_2=20$, both of which are significant at $\alpha=1\%$.

Chapter 17

Assignment 5.3

H_0 : There is no difference in height between the boys from the two sects.

H_1 : There is some difference between the two sects.

Test: Wald-Wolfowitz runs test.

Decision rule: at $\alpha=5\%$, reject H_0 in favour of H_1 if $T \leq 5$ ($n_1=9$, $n_2=12$).

$T=12.83$ (by averaging the different values of T resulting from 'reordering' the tied values) and so H_0 cannot be rejected.

Assignment 6.2

H_0 : There is no difference in swimming ability between the two groups.

H_1 : There is some difference between the groups.

Test: Wald-Wolfowitz test.

Decision rule: at $\alpha=5\%$, reject H_0 in favour of H_1 if $T \leq 6$ ($n_1=n_2=10$).
 $T=7$ and so H_0 cannot be rejected.

1.

H_0 : The sample values come from a random sequence.

H_1 : The sample values do not come from a random sequence.

Test: runs test.

Decision rule: at $\alpha_2=5\%$, reject H_0 in favour of H_1 if $T \leq 8$ or $T \geq 19$ ($n_1=12$, $n_2=13$).

$T=15$ and so H_0 cannot be rejected.

H_0 : The sample values come from a random sequence.

H_1 : The sample values do not come from a random sequence.

Test: runs up and down test.

Decision rule: at $\alpha_2=5\%$, reject H_0 in favour of H_1 if $U \leq 11$ or $U \geq 20$ ($n=24$).

$U=16$ and so H_0 cannot be rejected.

Chapter 19

Assignment 3.1

Based on the sign test, a 90% confidence interval for ϕ is (1.9, 3.7).

Assignment 3.2

Based on the sign test, a 90% confidence interval for ϕ is (138, 144).

Assignment 5.3

A 90% confidence interval for $\phi_A - \phi_B$ is (0, 11).

1.

A 90% confidence interval for $\phi_A - \phi_B$ is (-1.45, -0.1).

References

- Ansari, A. R. and R. A. Bradley 1960. Rank-sum tests for dispersion. *Ann. Math. Statist.* **31**, 1174-89.
- Arbuthnott, J. 1710. An argument for divine providence taken from the constant regularity observed in the births of both sexes. *Phil. Trans.* **27**, 186-90.
- Brown, G. W. and A. M. Mood 1951. On median tests for linear hypotheses. In *Proceedings of the Second Berkeley Symposium on Mathematical Statistics and Probability*, 159-66. University of California Press. (The method was also given in Mood A. M. 1950. *Introduction to the theory of statistics*. New York: McGraw-Hill.
- Dunn, O. J. 1964 Multiple comparisons using rank sums. *Technometrics* **6**, 241-52.
- Friedman, M. 1937. The use of ranks to avoid the assumption of normality implicit in the analysis of variance. *J. Am. Statist. Assoc.* **32**, 675-701.
- Goodman, L. A. 1954. Kolmogorov-Smirnov tests for psychological research. *Psychol. Bull.* **51**, 160-8.
- Iman, R. L. and W. J. Conover 1979. The use of the rank transform in regression. *Technometrics* **21**, 499-509.
- Jonckheere, A. R. 1954. A distribution-free k -sample test against ordered alternatives. *Biometrika* **41**, 133-45.
- Kendall, M. G. 1938. A new measure of rank correlation. *Biometrika* **30**, 81-3.
- Kolmogorov, A. N. 1933. Sulla determinazione empirica di una legge di distribuzione. *Giorn. Ist. Ital. Attuari* **4**, 83-91.
- Kruskal, W. H. 1952. A nonparametric test for the several sample problem. *Ann. Math. Statist.* **23**, 525-40.
- Kruskal, W. H. and W. A. Wallis 1952. Use of ranks in one criterion variance analysis. *J. Am. Statist. Assoc.* **47**, 583-621. 1953. Addendum. *Ibid.* **48**, 907-11.
- Lilliefors, W. H. 1967. On the Kolmogorov-Smirnov test for normality with mean and variance unknown. *J. Am. Statist. Assoc.* **62**, 399-402.
- Mann, H. B. and D. R. Whitney 1947. On a test of whether one of two random variables is stochastically larger than the other. *Ann. Math. Statist.* **18**, 50-60.
- Mood, A. M. 1950. *Introduction to the theory of statistics*. New York: McGraw-Hill.
- Mood, A. M. 1954. On the asymptotic efficiency of certain non-parametric two-sample tests. *Ann. Math. Statist.* **25**, 514-22.
- Olmstead, P. S. and J. W. Tukey 1947. A corner test for association. *Ann. Math. Statist.* **18**, 495-513.
- Page, E. B. 1963. Ordered hypotheses for multiple treatments: a significance test for linear ranks. *J. Am. Statist. Assoc.* **58**, 216-30.
- Pearson, K. 1900. On the criterion that a given system of deviations from the probable in the case of a correlated system of variables is such that it can reasonably be supposed to have arisen from random sampling. *Phil. Mag.* (5) **50**, 157-75.
- Rosenbaum, S. 1965. On some two-sample non-parametric tests. *J. Am. Statist. Assoc.* **60**, 1118-26.

- Siegel, S. and J. W. Tukey 1960. A non-parametric sum of ranks procedure for relative spread in unpaired samples. *J. Am. Statist. Assoc.* **55**, 429-45. 1961. Errata. *Ibid.* **56**, 1005.
- Smirnov, N. V. 1939. Estimate of deviation between empirical distribution functions in two independent samples. *Bull. Moscow Univ.* **2**, 3-16.
- Spearman, C. 1904. The proof and measurement of association between two things. *Am. J. Psychol.* **15**, 72-101.
- Terpstra, T. J. 1952. The asymptotic normality and consistency of Kendall's test against trend when ties are present in one ranking. *Indag. Math.* **14**, 327-33.
- Theil, H. 1950. A rank-invariant method of linear and polynomial regression analysis. 1. *Nederl. Akad. Wetensch. Proc. Ser. A* **53**, 386-92.
- Tukey, J. W. 1959. A quick, compact, two-sample test to Duckworth's specifications. *Technometrics* **1**, 31-48.
- Wald, A. and J. Wolfowitz 1940. On a test whether two samples are from the same population. *Ann. Math. Statist.* **11**, 147-62.
- Westernberg, J. 1948. Significance test for median and interquartile range in samples from continuous populations of any form. *Akad. Wetensch. Afdeeling Voor Wis.* **51**, 252-61.
- Wilcoxon, F. 1945. Individual comparisons by ranking methods. *Biometrics* **1**, 80-3.
- Wilcoxon, F. 1949. *Some rapid approximate statistical procedures*. American Cyanamid Co., Stamford Research Laboratories.
- Worthington, P. L. 1982. Match tests for non-parametric analysis of variance problems. PhD Thesis, Nottingham University.

Index

- alternative hypothesis 46
- association between two variables 231
 - chi-squared test 232
 - Fisher's exact test 338
- best conservative critical values 58
- binomial distribution 29
 - mean and standard deviation 34
 - normal approximation to 41
- Brown and Mood's regression method 220
 - procedure 221
- chi-squared distribution 43
- chi-squared goodness-of-fit test 80
 - statistic 81
 - critical regions 82
 - small expected frequencies 84
 - use with normal distribution, mean and standard deviation known 85; mean and standard deviation unknown 88
 - computer program 104
 - table of critical values 371
- chi-squared test for association 232
 - statistic 233
 - critical regions 236
 - small expected frequencies 237
 - Yates' correction 238
 - computer program 240
 - table of critical values 371
- computer programs, note on 75
- confidence intervals 348
- confidence intervals for the median 351
 - method 351
 - theory 352
 - large sample sizes 353
- confidence intervals for location differences 354
 - graphical method 355
 - arithmatcal method 357
 - theory 358
 - large sample sizes 359
 - computer program 364
- confidence interval for a matched-pair difference 359
 - method 360
 - theory 361
 - large sample sizes 363
- computer program 365
- continuity correction 42
- continuous variables 4
- correlation tests 169
 - Spearman's test 169
 - Kendall's test 177
 - discussion 182
 - Olmstead-Tukey test 212
- critical region 50
- cumulative distribution function (cdf)
 - population 11
 - sample 16
- discrete variable 5
- dispersion, measures of 12
- distribution free vs classical statistics 348
- Dunn's multiple comparisons method 243
 - k independent samples 244
 - k related samples 278
- Fisher's exact test for association 338
 - statistic 340
 - critical regions 340
 - two-sided tests 341
 - table of critical values 410-12
- frequency distributions 9
- Friedman's test for k related samples 265
 - statistics 267
 - critical regions 268
 - null distributions 270
 - large sample sizes 271
 - ties 271
 - computer program 282
 - table of critical values 395
- goodness-of-fit tests 79
 - chi-squared test 80
 - Kolmogorov-Smirnov test 89
 - Lilliefors' test for normality 100
- histogram, population 9
- histogram, sample 15
- hypothesis tests 48
- Iman-Conover monotonic regression
 - method 201
 - method 202

- theory 205
- computer program 210
- interaction 304
- k independent samples 243
 - Kruskal-Wallis test 244
 - Mood's median test 253
 - multiple comparisons 256
- k related samples 263
 - Friedman's test 265
 - Match tests 273
 - multiple comparisons 278
- k samples, ordered alternative hypotheses 285
 - Terpstra-Jonckheere test 286
 - Page's test 291
 - Match tests 295
- Kendall's rank correlation coefficient, T 177
 - statistic 178
 - graphical method 178
 - critical regions 180
 - arithmetical method 181
 - one- and two-sided tests 181
 - ties 182
 - null distributions 181
 - large sample sizes 182
 - computer program 188
 - table of critical values 391
- Kolmogorov-Smirnov goodness-of-fit test 89
 - statistic 91
 - critical regions 92
 - comparison with chi-squared test 94
 - one-sided alternatives 95
 - large sample sizes 97
 - use with discrete distributions 98
 - table of critical values 374
- Kolmogorov-Smirnov two sample test 149
 - statistic 150
 - critical regions 152
 - comparisons with other tests 152
 - one- and two-sided tests 154
 - ties 154
 - null distributions 155
 - large sample sizes 156
 - computer program 158
 - table of critical values 387-9
- Kruskal-Wallis test for k independent samples 244
 - statistic 245
 - critical regions 248
 - ties 259
 - null distributions 251
 - computer program 262
 - table of critical values 392-4
- latin squares designs 314
 - method of testing 317
 - critical regions 318
- Lilliefors' test for normality 100
- critical regions 101
- computer program 104
- table of critical values 374
- location, measures of 10
- Mann-Whitney test, two-independent samples 109
 - statistic 110
 - critical regions 112
 - Wilcoxon's version 113
 - one- and two-sided tests 114
 - ties 115
 - null distributions 116
 - large sample sizes 117
 - relation between rank-sums and U^* 118
 - computer program 127
 - table of critical values 375-6
- Match tests for k related samples 273
 - statistics (M_1 & M_2) 273
 - critical regions 274
 - ties 275
 - large sample sizes 277
 - computer program 284
 - table of critical values for M_1 396
 - table of critical values for M_2 397
- Match tests for ordered alternatives 295
 - statistics (L_1 and L_2) 295
 - critical regions 296
 - ties 297
 - null distributions 297
 - large samples 298
 - computer program 302
 - table of critical values for L_1 401
 - table of critical values for L_2 402
- Match tests for interaction 310
 - statistics (S_1 and S_2) 311
 - critical regions 313
 - large experiment sizes 313
 - computer program 319
 - table of critical values for S 403
 - table of critical values for S 404
- matches 273
- mean absolute deviation, population 13
- mean, population 10
- mean, sample 16
- median v. mean 44
- median, population 10
- median, sample 16
 - quick calculation of 219
- Mood's median test for k independent samples 253
 - statistic 254
 - critical regions 255
 - table of critical values 371
- Mood's two-sample median test 341
 - statistics 342
 - critical regions 343
 - Yates' correction 343
- Mood-Westenberg two-sample spread test 344

- statistic 344
 - critical regions 347
- normal distribution 34
- null distribution 50
- null hypothesis 46
- Olmstead-Tukey test for correlation 212
 - statistic 213
 - critical regions 216
 - discussion 217
 - one- and two-sided tests 218
 - ties 218
 - null distributions 219
 - large sample sizes 219
- one-sided and two-sided tests 54
- Page's test for k related samples, ordered alternative hypothesis 291
 - statistic 292
 - critical regions 293
 - null distributions 294
 - large sample sizes 294
 - computer program 301
 - table of critical values 400
- populations 5
 - real-life 6
- power of tests 58
- probability 18
- probability distribution 19
- probability density function (pdf) 21
- probability laws
 - addition 22
 - multiplication 22
- random variables 23
- regression 189
 - Theil's incomplete method 192
 - Iman-Conover method 201
 - test for the slope 198, 224
 - Brown and Mood's method 220
 - test for intercept 228
- Rosenbaum's two-sample test 144
 - statistic 146
 - critical regions 147
 - comparison with other two-sample tests 147
 - one- and two-sided test 148
 - ties 148
 - null distributions 148
 - large sample sizes 148
 - table of critical values 383-6
- Runs test for randomness 324
 - statistic 326
 - critical regions 326
 - ties 327
 - one-sided tests 327
 - large sample sizes 327
 - table of critical values 405-8
- runs, idea of 323
- Runs-up and -down test for randomness 328
 - statistic 330
 - critical regions 330
 - ties 331
 - one-sided tests 311
 - large sample sizes 332
 - table of critical value 409
- samples 15
- sensitivity of a test 58
- Siegel-Tukey two-sample dispersion test 130
 - statistic 132
 - critical regions 133
 - one- and two-sided tests 134
 - ties 135
 - null distributions 135
 - large sample sizes 135
 - computer program 141
 - table of critical values 375-6
- Sign test, one-sample location 65
 - statistic 66
 - critical regions 66
 - one- and two-sided tests 67
 - observations equal to hypothesised median 68
 - null distributions 68
 - large sample sizes 69
 - table of critical values 372
- Sign test for matched pairs 164
 - table of critical values 372
- significance level 51
- Spearman's rank correlation coefficient, r_s
 - 169
 - statistic 172
 - critical regions 173
 - alternative derivation of r_s 175
 - one- and two-sided tests 176
 - ties 177
 - null distributions 177
 - large sample sizes 177
 - non-numeric data example 184
 - computer program 187
 - table of critical values 390
- standard deviation, population 14
- Terpstra-Janckheer test, for ordered alternative hypothesis 286
 - statistic 288
 - critical regions 288
 - ties 289
 - null distributions 289
 - large sample sizes 290
 - computer program 300
 - table of critical values 398-9
- test statistic 47
- Theil's 'incomplete' regression method 192
 - procedure 194; computer program 208
- Tukey's two-sample location test 118
 - statistic 120
 - critical values 121

- one- and two-sided tests 122
- ties 123
- null distributions 124
- large sample sizes 124
- table of critical values 377-8
- Tukey-type two-sample test for dispersion 136
 - statistic 136
 - critical regions 137
 - one- and two-sided tests 138
 - ties 138
 - null distributions 139
 - large sample sizes 139
 - table of critical values 379-82
- two independent samples, location differences
 - Mann-Whitney test 109
 - Tukey's quick test 118
 - Mood's median test 341
- two independent samples, dispersion tests 129
 - Siegel-Tukey test 130
 - Tukey-type test 136
 - Mood-Westenberg test 344
- two independent samples, general differences 143
 - Rosenbaum's test 144
 - Kolmogorov-Smirnov test 149
- two related samples 160
 - Wilcoxon's signed-rank test 161
 - sign test 164
- Type I error 52
- Type II error 52
- uniform distribution 26
- variance, population 14
- Wald-Wolfowitz two-sample runs test 332
 - statistic 334
 - critical regions 335
 - large sample sizes 336
 - table of critical values 405
- weakness of distribution-free dispersion tests 135
- Wilcoxon signed-rank test, one-sample 69
 - restrictions 70
 - statistic 70
 - critical regions 70
 - compared with sign test 72
 - one- and two-sided tests 72
 - zero differences and ties 73
 - null distributions 74
 - large sample sizes 75
 - table of critical values 373
- Wilcoxon's signed-rank test for matched-pairs 161
 - statistic 162
 - critical regions 162
 - one- and two-sided tests 163
 - ties and zero differences 163
 - null distributions 163
 - computer program 166
 - table of critical values 373
- Wilcoxon's interaction test 307
 - statistic 308
 - critical regions 309
- Yates' correction 238, 343

198
ry
tio

15366498

SUBJECT TO RECALL **DATE DUE**

[illegible]

Demco, Inc. 38-293

OCT 13 1989