

1 RANK TESTS FOR COMPARING TWO TREATMENTS

1

1. Ranks in the comparison of two treatments, 1
2. The Wilcoxon rank-sum test, 5
3. Asymptotic null distribution of the Wilcoxon statistic, 13
4. The treatment of ties, 18
5. Two-sided alternatives, 23
6. The Siegel-Tukey and Smirnov tests, 32
7. Further developments, 40

Other approximations to the distribution of W_s ;
Censored observations; Early termination; Power;
Permutation tests.

8. Problems, 43
9. References, 52

2 COMPARING TWO TREATMENTS OR ATTRIBUTES IN A POPULATION MODEL

55

1. Population models, 55
2. Power of the Wilcoxon rank-sum test, 65
3. Asymptotic power, 69
4. Comparison with Student's t -test, 76
5. Estimating the treatment effect, 81
6. Confidence procedures, 91
7. Further developments, 95

The Behrens-Fisher problem; The Normal Scores test;
Increasing the number of levels to improve sensitivity; Small-sample power; Large-sample power and efficiency; Efficiency in the presence of ties; Optimality properties; Additional properties of $\hat{\Delta}$; Efficiency of the Siegel-Tukey test; The scale tests of Capon and Klotz; The Savage (or exponential scores) test; Scale tests with unknown location; Power and efficiency of the Smirnov test; Sequential rank tests; The permutation t -test.

8. Problems, 106
9. References, 114

3 BLOCKED COMPARISONS FOR TWO TREATMENTS

120

1. The sign test for paired comparisons, 120
2. The Wilcoxon signed-rank test, 123
3. Combining data from several experiments or blocks, 132
4. A balanced design for paired comparisons, 141
5. Further developments, 143
Power of the sign and Wilcoxon tests; Alternative treatment of zeros; Tests against omnibus alternatives; Efficiency and generalizations of the blocked comparisons test W_s .
6. Problems, 146
7. References, 153

4 PAIRED COMPARISONS IN A POPULATION MODEL AND THE ONE-SAMPLE PROBLEM

156

1. Power and uses of the sign test, 156
2. Power of the signed-rank Wilcoxon test, 164
3. Comparison of sign, Wilcoxon, and t -tests, 171
4. Estimation of a location parameter or treatment effect, 175
5. Confidence procedures, 181
6. Further developments, 185
Power and efficiency of the sign test; The absolute Normal Scores test; Power and efficiency of the Wilcoxon and absolute Normal Scores test; Tests of symmetry; A generalized set of confidence points; Bounded-length sequential confidence intervals for θ ; Robust estimation; Some optimum properties of tests and estimators; Departures from assumption.
7. Problems, 191
8. References, 199

5 THE COMPARISON OF MORE THAN TWO TREATMENTS

202

1. Ranks in the comparison of several treatments, 202
2. The Kruskal-Wallis test, 204
3. $2 \times t$ Contingency tables, 210
4. Population models, 219
5. One-sided procedures, 226
Comparing several treatments with a control; Testing equality against ordered alternatives.
6. Selection and ranking procedures, 238
Ranking several treatments; Selecting the best of several treatments.
7. Further developments, 247
Power and efficiency; Estimation of several differences in location; The estimation of contrasts; Normal Scores and Smirnov tests for the s -sample problem.

8. Problems, 250
9. References, 257

6 RANDOMIZED COMPLETE BLOCKS

260

1. Ranks in randomized complete blocks, 260
2. The tests of Friedman, Cochran, and McNemar, 262
3. Aligned ranks, 270
4. Population models and efficiency, 273
5. Further developments, 279
 - More general blocks; One-sided tests and ranking procedures;
 - Estimation of treatment differences and other contrasts;
 - Combination of independent tests.
6. Problems, 281
7. References, 285

7 TESTS OF RANDOMNESS AND INDEPENDENCE

287

1. The hypothesis of randomness, 287
2. Testing against trend, 290
3. Testing for independence, 297
4. $s \times t$ Contingency tables, 303
5. Further developments, 311
 - Pitman efficiency of D ; Estimating the regression coefficient β ;
 - Tests of randomness based on runs; Other tests of independence; Power and efficiency of tests of independence; Contingency tables.
6. Problems, 317
7. References, 322

APPENDIX

327

1. Expectation and variance formulas, 327
2. Some standard distributions, 339
 - The binomial distribution; The hypergeometric distribution;
 - The normal distribution; The Cauchy, logistic, and double-exponential distributions; The rectangular (uniform) and exponential distributions; The χ^2 -distribution; Order statistics.
3. Convergence in probability and in law, 345
4. Sampling from a finite population, 352
5. U-statistics, 362
6. Pitman efficiency, 371
7. Some multivariate distributions, 380
 - The multinomial distribution; The multiple hypergeometric distribution; The multivariate normal distribution.

8. Convergence of random vectors, 386
9. Problems, 396
10. References, 405

EPILOGUE

407

TABLES

413

- A Number of combinations of N things taken n at a time, 413
- B Wilcoxon rank-sum distribution, 414
- C Area under the normal curve, 417
- D Square roots, 418
- E Smirnov Exact upper-tail probabilities, 419
- F Smirnov limiting distribution, 421
- G Distribution of sign-test statistics, 422
- H Wilcoxon signed-rank distribution, 424
- I Kruskal-Wallis upper-tail probabilities, 428
- J(a) χ^2 upper-tail probabilities for $\nu = 2, 3, 4, 5$ degrees of freedom, 433
- J(b) Critical values c of χ^2 with $\nu = 6(1)40(5)100$ degrees of freedom, 434
- K Upper-tail probabilities of Jonckheere's statistic, 435
- L Amalgamation probabilities for Chacko's test, 436
- M Upper-tail probabilities of Friedman's statistic, 437
- N Distribution of Spearman's statistic, 439

ACKNOWLEDGMENTS FOR TABLES, 440

ANSWERS TO SELECTED PROBLEMS, 441

DATA GUIDE (TITLES FOR DATA PRESENTED IN THE TEXT), 451

AUTHOR INDEX, 453

SUBJECT INDEX, 457