Formulas and Tables 6e.pdf

Formulas and Tables from

Hurlburt, R. T. (2017). *Comprehending behavioral statistics* (6th ed.). Dubuque, IA: Kendall Hunt.

Frequently used statistical formulas (see Appendix C for a complete list)

Description	Formula	Equation Number	Page
Probability of an event	$P(E) = \frac{\text{number of outcomes favorable to } E}{\text{total number of possible outcomes}}$	(1.1)	9
Mean of a population and sample	$\mu = \frac{\sum X_i}{N}$ (population) $\quad \bar{X} = \frac{\sum X_i}{n}$ (sample)	(4.2) (4.1)	76 72
Range	Range = highest value – lowest value	(5.1)	88
Standard deviation of a population	$\sigma = \sqrt{\frac{\sum (X_i - \mu)^2}{N}}$	(5.5)	91
Standard deviation of a sample	$s = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n-1}}$	(5.7)	92
Transformation from a raw score to a standard score	$z = \frac{X - \mu}{\sigma}$ (population) $\quad z = \frac{X - \bar{X}}{s}$ (sample)	(6.1) (6.2)	116 116
Transformation from a z score to a raw score	$X = \mu + z\sigma$ (population) $\quad X = \bar{X} + zs$ (sample)	(6.3) (6.4)	133 136
Standard error of the mean in a population and sample	$\sigma_{\bar{X}} = \frac{\sigma}{\sqrt{n}}$ (population) $\quad s_{\bar{X}} = \frac{s}{\sqrt{n}}$ (sample)	(7.1) (8.2)	162 187
Standard score in the distribution of means in a population	$z = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}}$	(7.2)	163
Confidence interval for the population mean when σ is known and unknown	σ known: $\bar{X} - z_{cv}(\sigma_{\bar{X}}) \le \mu \le \bar{X} + z_{cv}(\sigma_{\bar{X}})$ σ unknown: $\bar{X} - t_{cv}(s_{\bar{X}}) \le \mu \le \bar{X} + t_{cv}(s_{\bar{X}})$ $\quad [df = n - 1]$	(8.1) (8.3)	181 189
General formula for the test statistic	$\text{test statistic} = \frac{\text{sample statistic} - \text{population parameter}}{\text{standard error of the sample statistic}}$	(9.1)	219
Critical value of the sample mean when σ is known and unknown	$\bar{X}_{cv} = \mu \pm z_{cv}(\sigma_{\bar{X}})$ (σ known) $\quad \bar{X}_{cv} = \mu \pm t_{cv}(s_{\bar{X}})$ (σ unknown)	(10.2) (10.5)	235 243
Test statistic (t), one-sample test for the mean when σ is unknown	$t = \frac{\bar{X} - \mu}{s_{\bar{X}}}$ $\quad [df = n - 1]$	(10.4)	243

Description	Formula	Equation Number	Page
Effect size index d, one-sample test for the mean when σ is known	$d = \frac{\lvert \bar{X}_{obs} - \mu \rvert}{\sigma}$ or $d = \frac{\bar{X}_{obs} - \mu}{\sigma}$ (nondirectional test) (directional test)	(10.3)	241
Effect size index d, one-sample test for the mean when σ is unknown	$d = \frac{\lvert \bar{X}_{obs} - \mu \rvert}{s}$ or $d = \frac{\bar{X}_{obs} - \mu}{s}$ (nondirectional test) (directional test)	(10.6)	243
Test statistic (t), two-independent-samples test for means	$t = \frac{\bar{X}_1 - \bar{X}_2}{s_{\bar{X}_1 - \bar{X}_2}}$ $[df = n_1 + n_2 - 2]$	(11.2)	271
Standard error of the difference between two means	$s_{\bar{X}_1 - \bar{X}_2} = \sqrt{\frac{s^2_{pooled}}{n_1} + \frac{s^2_{pooled}}{n_2}}$	(11.3)	272
Pooled variance when sample sizes are equal	$s^2_{pooled} = \frac{s_1^2 + s_2^2}{2}$ [only when $n_1 = n_2$]	(11.4)	272
Pooled variance for equal or unequal sample sizes, alternative form	$s^2_{pooled} = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$	(11.5a)	273
Standard error of the difference between two means when sample sizes are equal	$s_{\bar{X}_1 - \bar{X}_2} = \sqrt{2\frac{s^2_{pooled}}{n}}$ [only when $n_1 = n_2 = n$]	(11.6)	274
Effect size index d, two-independent-samples test for means	$d = \frac{\lvert (\bar{X}_1 - \bar{X}_2)_{obs} \rvert}{s_{pooled}}$ or $d = \frac{(\bar{X}_1 - \bar{X}_2)_{obs}}{s_{pooled}}$ (nondirectional test) (directional test)	(11.7)	278
Test statistic (t), two-dependent-samples test for means	$t = \frac{\bar{D}}{s_{\bar{D}}}$ $[df = n - 1]$	(12.3)	306
Standard error of the mean differences	$s_{\bar{D}} = \frac{s_D}{\sqrt{n}}$ [where n is the number of difference scores]	(12.4)	306
Standard deviation of the differences, mean squared deviation and computational forms	$s_D = \sqrt{\frac{\sum (D_i - \bar{D})^2}{n - 1}} = \sqrt{\frac{\sum D_i^2 - \frac{(\sum D_i)^2}{n}}{n - 1}}$	(12.5)	306
Effect size index d, two-dependent-samples test for means	$d = \frac{\lvert \bar{D}_{obs} \rvert}{s_D}$ or $d = \frac{\bar{D}_{obs}}{s_D}$ (nondirectional test) (directional test)	(12.6)	310

Description	Formula	Equation Number	Page
Power	$\text{power} = 1 - \beta$	(13.1)	330
Population effect size index	$d_{\text{population}} = \dfrac{\mu_{\text{real}} - \mu_{H_0}}{\sigma}$ (one-sample test) $d_{\text{population}} = \dfrac{\mu_1 - \mu_2}{\sigma}$ (two-independent-samples test)	(13.2) (13.3)	340 340
	$d_{\text{population}} = \dfrac{\mu_{D_{\text{real}}}}{\sigma_D}$ (two-dependent-samples test)	(13.4)	340
Test statistic (F), analysis of variance	$F = \dfrac{\text{MS}_\text{B}}{\text{MS}_\text{W}} = \dfrac{\text{between-group point-estimate of } \sigma^2}{\text{within-group point-estimate of } \sigma^2}$	(14.2a)	361
Variance of the sample means, definitional formula	$s_{\bar{X}}^2 = \dfrac{\sum(\bar{X}_j - \bar{X}_\text{G})^2}{k-1}$	(14.3)	359
Mean square between groups, definitional formula	$\text{MS}_\text{B} = s_{\bar{X}}^2(n)$ [only if $n_1 = n_2 = \cdots = n_k = n$]	(14.4)	360
Pooled variance, k equal-sized groups	$s_{\text{pooled}}^2 = \dfrac{s_1^2 + s_2^2 + s_3^2 + \cdots + s_k^2}{k}$ [only if equal n_j]	(14.5)	361
Mean square within groups, definitional formula	$\text{MS}_\text{W} = s_{\text{pooled}}^2$	(14.6)	361
Degrees of freedom for the analysis of variance	$df_\text{B} = k - 1$ (between groups) $df_\text{W} = n_\text{G} - k$ (within groups) $df_\text{T} = n_\text{G} - 1$ (total)	(14.7) (14.8c) (14.13)	362 363 369
Mean squares	$\text{MS}_\text{B} = \text{SS}_\text{B} / df_\text{B}$ (between groups) $\text{MS}_\text{W} = \text{SS}_\text{W} / df_\text{W}$ (within groups)	(14.14) (14.15)	369 369
Total sum of squares	$\text{SS}_\text{T} = \sum(X_{ij} - \bar{X}_\text{G})^2$	(14.9)	365
Sum of squares within groups	$\text{SS}_\text{W} = \sum(X_{ij} - \bar{X}_j)^2$	(14.10)	366
Sum of squares between groups	$\text{SS}_\text{B} = \sum(\bar{X}_j - \bar{X}_\text{G})^2$	(14.11)	368
ANOVA effect size	$f = \dfrac{s_{\bar{X}}}{s_{\text{pooled}}}$ (as ratio of standard deviations) $R^2 = \dfrac{\text{SS}_\text{B}}{\text{SS}_\text{T}}$ (as proportion of variance accounted for) $d_\text{M} = \dfrac{\bar{X}_{\max} - \bar{X}_{\min}}{s_{\text{pooled}}}$ (by analogy to two samples)	(14.16) (14.17) (14.18)	373 374 374
Studentized range statistic for Tukey's post hoc tests	$Q = \dfrac{\lvert \bar{X}_i - \bar{X}_j \rvert}{\sqrt{\text{MS}_\text{W} / \tilde{n}}}$	(15.2)	Res. 15A.1

Description	Formula	Equation Number	Page
Harmonic mean of sample sizes	$\tilde{n} = \dfrac{k}{\dfrac{1}{n_1} + \dfrac{1}{n_2} + \dfrac{1}{n_3} + \cdots + \dfrac{1}{n_k}}$	(15.3)	Res. 15A.1
General form of the test statistic	$\text{Test statistic} = \dfrac{\text{sample comparison} - \text{population comparison}}{\text{standard error of the sample comparison}}$	(15.9)	Res. 15B.3
Test statistic (F) for repeated-measures ANOVA	$F = \dfrac{\text{MS}_{\text{between occasions}}}{\text{MS}_{\text{residual}}}$	(15.11)	405
Partition of the total sum of squares and total df in repeated-measures ANOVA	$\text{SS}_{\text{total}} = \text{SS}_{\text{between occasions}} + \text{SS}_{\text{between subjects}} + \text{SS}_{\text{residual}}$ $df_{\text{total}} = df_{\text{between occasions}} + df_{\text{between subjects}} + df_{\text{residual}}$ $= nk - 1$	(15.12) (15.13)	Res. 15C.4 Res. 150.4
Pearson product-moment correlation coefficient for a sample	$r = \dfrac{\sum z_X z_Y}{n-1} = \dfrac{\sum XY - \dfrac{\sum X \sum Y}{n}}{\sqrt{\left[\sum X^2 - \dfrac{\left(\sum X\right)^2}{n}\right]\left[\sum Y^2 - \dfrac{\left(\sum Y\right)^2}{n}\right]}}$	(16.1) (16.1a)	432 433
Spearman rank correlation coefficient	$r_s = 1 - \dfrac{6\sum D_i^2}{n(n^2-1)}$	(16.5)	443
Regression line	$\hat{Y} = bX + a$ (raw score form) $\quad \hat{z}_Y = rz_X$ (standard form)	(17.1) (17.8)	463 479
Slope of the regression line	$b = r\dfrac{s_Y}{s_X}$ or $b = \dfrac{\sum XY - \dfrac{\sum X \sum Y}{n}}{\sum X^2 - \dfrac{\left(\sum X\right)^2}{n}}$	(17.2) (17.2a)	469 471
Intercept of the regression line	$a = \overline{Y} - b\overline{X}$	(17.3)	470
Error of prediction for the ith individual	$e_i = Y_i - \hat{Y}_i$	(17.4)	472
Standard error of estimate	$s_e = \sqrt{\dfrac{\sum e_i^2}{n-2}} = s_Y\sqrt{1-r^2}\sqrt{\dfrac{n-1}{n-2}}$	(17.6) (17.7)	475 475
χ^2 test statistic for goodness of fit test and test of independence	$\chi^2 = \sum \dfrac{(O_i - E_i)^2}{E_i} \quad [df = k - 1]$	(18.1)	504
Expected frequency of cell in contingency table	$\text{expected frequency of cell } rc = \dfrac{f_r f_c}{N}$	(18.3)	512

TABLE A.2 Critical values of t *(see page 542)*

	Level of significance (α) for directional (one-tailed) test			
	.05	**.025**	**.01**	**.005**
	Level of significance (α) for nondirectional (two-tailed) test			
***df* = *n* – 1**	**.10**	**.05**	**.02**	**.01**
1	6.314	12.706	31.821	63.657
2	2.920	4.303	6.965	9.925
3	2.353	3.182	4.541	5.841
4	2.132	2.776	3.747	4.604
5	2.015	2.571	3.365	4.032
6	1.943	2.447	3.143	3.707
7	1.895	2.365	2.998	3.499
8	1.860	2.306	2.896	3.355
9	1.833	2.262	2.821	3.250
10	1.812	2.228	2.764	3.169
11	1.796	2.201	2.718	3.106
12	1.782	2.179	2.681	3.055
13	1.771	2.160	2.650	3.012
14	1.761	2.145	2.624	2.977
15	1.753	2.131	2.602	2.947
16	1.746	2.120	2.583	2.921
17	1.740	2.110	2.567	2.898
18	1.734	2.101	2.552	2.878
19	1.729	2.093	2.539	2.861
20	1.725	2.086	2.528	2.845
21	1.721	2.080	2.518	2.831
22	1.717	2.074	2.508	2.819
23	1.714	2.069	2.500	2.807
24	1.711	2.064	2.492	2.797
25	1.708	2.060	2.485	2.787
26	1.706	2.056	2.479	2.779
27	1.703	2.052	2.473	2.771
28	1.701	2.048	2.467	2.763
29	1.699	2.045	2.462	2.756
30	1.697	2.042	2.457	2.750
40	1.684	2.021	2.423	2.704
60	1.671	2.000	2.390	2.660
120	1.658	1.980	2.358	2.617
∞	1.645	1.960	2.326	2.576

When $df = \infty$, $t_{cv} = z_{cv}$

Adapted from Table III of R. A. Fisher & F. Yates, *Statistical Tables for Biological, Agricultural, and Medical Research.* Sixth Edition, published by Longman Group UK, Ltd., (1974). Adapted with permission.

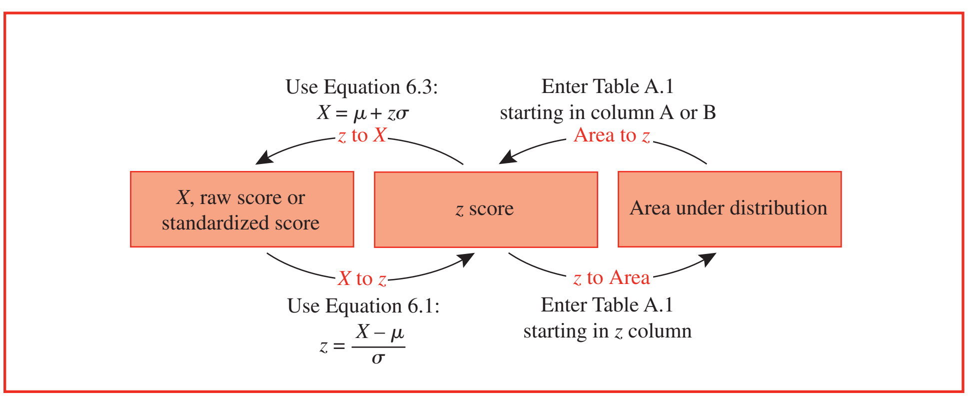


FIGURE 6.20 "Know/want" diagram of the relationships among raw scores, z scores, and tabled areas

APPENDIX A: Statistical Tables

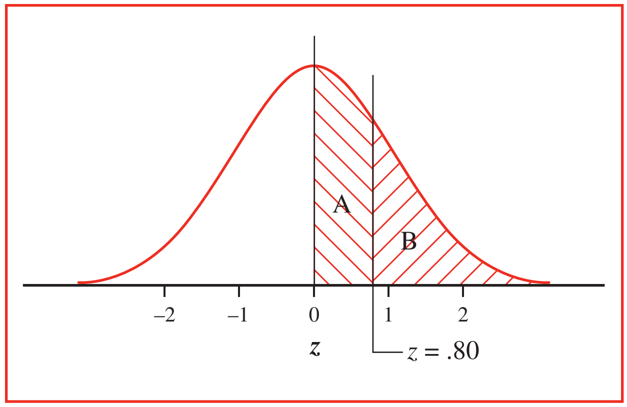
TABLE A.1 Proportions of areas under the normal curve

For a description in the text, see page 128.

AN EXAMPLE USING TABLE A.1

If z = .80, then the area between z = 0 and z = .80 is shown in the region marked "A"; that area is .2881, or 28.81% of the total area under the curve.

The area beyond z is shown in the region marked "B"; that area is .2119, or 21.19% of the total area under the curve.



z = .80; the area in region A is .2881; the area in region B is .2119

z	Area between mean and *z* (A)	Area beyond *z* (B)	*z*	Area between mean and *z* (A)	Area beyond *z* (B)
.00	.0000	.5000	.30	.1179	.3821
.01	.0040	.4960	.31	.1217	.3783
.02	.0080	.4920	.32	.1255	.3745
.03	.0120	.4880	.33	.1293	.3707
.04	.0160	.4840	.34	.1331	.3669
.05	.0199	.4801	.35	.1368	.3632
.06	.0239	.4761	.36	.1406	.3594
.07	.0279	.4721	.37	.1443	.3557
.08	.0319	.4681	.38	.1480	.3520
.09	.0359	.4641	.39	.1517	.3483
.10	.0398	.4602	.40	.1554	.3446
.11	.0438	.4562	.4I	.1591	.3409
.12	.0478	.4522	.42	.1628	.3372
.13	.0517	.4483	.43	.1664	.3336
.14	.0557	.4443	.44	.1700	.3300
.15	.0596	.4404	.45	.1736	.3264
.16	.0636	.4364	.46	.1772	.3228
.17	.0675	.4325	.47	.1808	.3192
.18	.0714	.4286	.48	.1844	.3156
.19	.0753	.4247	.49	.1879	.3121
.20	.0793	.4207	.50	.1915	.3085
.21	.0832	.4168	.51	.1950	.3050
.22	.0871	.4129	.52	.1985	.3015
.23	.0910	.4090	.53	.2019	.2981
.24	.0948	.4052	.54	.2054	.2946
.25	.0987	.4013	.55	.2088	.2912
.26	.1026	.3974	.56	.2123	.2877
.27	.1064	.3936	.57	.2157	.2843
.28	.1103	.3897	.58	.2190	.2810
.29	.1141	.3859	.59	.2224	.2776

(continues)

TABLE A.1 Proportions of areas under the normal curve *(continued)*

z	Area between mean and *z* (A)	Area beyond *z* (B)	*z*	Area between mean and *z* (A)	Area beyond *z* (B)
.60	.2257	.2743	1.10	.3643	.1357
.61	.2291	.2709	1.11	.3665	.1335
.62	.2324	.2676	1.12	.3686	.1314
.63	.2357	.2643	1.13	.3708	.1292
.64	.2389	.2611	1.14	.3729	.1271
.65	.2422	.2578	1.15	.3749	.1251
.66	.2454	.2546	1.16	.3770	.1230
.67	.2486	.2514	1.17	.3790	.1210
.68	.2517	.2483	1.18	.3810	.1190
.69	.2549	.2451	1.19	.3830	.1170
.70	.2580	.2420	1.20	.3849	.1151
.71	.2611	.2389	1.21	.3869	.1131
.72	.2642	.2358	1.22	.3888	.1112
.73	.2673	.2327	1.23	.3907	.1093
.74	.2704	.2296	1.24	.3925	.1075
.75	.2734	.2266	1.25	.3944	.1056
.76	.2764	.2236	1.26	.3962	.1038
.77	.2794	.2206	1.27	.3980	.1020
.78	.2823	.2177	1.28	.3997	.1003
.79	.2852	.2148	1.29	.4015	.0985
.80	.2881	.2119	1.30	.4032	.0968
.81	.2910	.2090	1.31	.4049	.0951
.82	.2939	.2061	1.32	.4066	.0934
.83	.2967	.2033	1.33	.4082	.0918
.84	.2995	.2005	1.34	.4099	.0901
.85	.3023	.1977	1.35	.4115	.0885
.86	.3051	.1949	1.36	.4131	.0869
.87	.3078	.1922	1.37	.4147	.0853
.88	.3106	.1894	1.38	.4162	.0838
.89	.3133	.1867	1.39	.4177	.0823
.90	.3159	.1841	1.40	.4192	.0808
.91	.3186	.1814	1.41	.4207	.0793
.92	.3212	.1788	1.42	.4222	.0778
.93	.3238	.1762	1.43	.4236	.0764
.94	.3264	.1736	1.44	.4251	.0749
.95	.3289	.1711	1.45	.4265	.0735
.96	.3315	.1685	1.46	.4279	.0721
.97	.3340	.1660	1.47	.4292	.0708
.98	.3365	.1635	1.48	.4306	.0694
.99	.3389	.1611	1.49	.4319	.0681
1.00	.3413	.1587	1.50	.4332	.0668
1.01	.3438	.1562	1.51	.4345	.0655
1.02	.3461	.1539	1.52	.4357	.0643
1.03	.3485	.1515	1.53	.4370	.0630
1.04	.3508	.1492	1.54	.4382	.0618
1.05	.3531	.1469	1.55	.4394	.0606
1.06	.3554	.1446	1.56	.4406	.0594
1.07	.3577	.1423	1.57	.4418	.0582
1.08	.3599	.1401	1.58	.4429	.0571
1.09	.3621	.1379	1.59	.4441	.0559

(continues)

TABLE A.1 Proportions of areas under the normal curve *(continued)*

z	Area between mean and *z* (A)	Area beyond *z* (B)	*z*	Area between mean and *z* (A)	Area beyond *z* (B)
1.60	.4452	.0548	2.10	.4821	.0179
1.61	.4463	.0537	2.11	.4826	.0174
1.62	.4474	.0526	2.12	.4830	.0170
1.63	.4484	.0516	2.13	.4834	.0166
1.64	.4495	.0505	2.14	.4838	.0162
1.65	.4505	.0495	2.15	.4842	.0158
1.66	.4515	.0485	2.16	.4846	.0154
1.67	.4525	.0475	2.17	.4850	.0150
1.68	.4535	.0465	2.18	.4854	.0146
1.69	.4545	.0455	2.19	.4857	.0143
1.70	.4554	.0446	2.20	.4861	.0139
1.71	.4564	.0436	2.21	.4864	.0136
1.72	.4573	.0427	2.22	.4868	.0132
1.73	.4582	.0418	2.23	.4871	.0129
1.74	.4591	.0409	2.24	.4875	.0125
1.75	.4599	.0401	2.25	.4878	.0122
1.76	.4608	.0392	2.26	.4881	.0119
1.77	.4616	.0384	2.27	.4884	.0116
1.78	.4625	.0375	2.28	.4887	.0113
1.79	.4633	.0367	2.29	.4890	.0110
1.80	.4641	.0359	2.30	.4893	.0107
1.81	.4649	.0351	2.31	.4896	.0104
1.82	.4656	.0344	2.32	.4898	.0102
1.83	.4664	.0336	2.33	.4901	.0099
1.84	.4671	.0329	2.34	.4904	.0096
1.85	.4678	.0322	2.35	.4906	.0094
1.86	.4686	.0314	2.36	.4909	.0091
1.87	.4693	.0307	2.37	.4911	.0089
1.88	.4699	.0301	2.38	.4913	.0087
1.89	.4706	.0294	2.39	.4916	.0084
1.90	.4713	.0287	2.40	.4918	.0082
1.91	.4719	.0281	2.41	.4920	.0080
1.92	.4726	.0274	2.42	.4922	.0078
1.93	.4732	.0268	2.43	.4925	.0075
1.94	.4738	.0262	2.44	.4927	.0073
1.95	.4744	.0256	2.45	.4929	.0071
1.96	.4750	.0250	2.46	.4931	.0069
1.97	.4756	.0244	2.47	.4932	.0068
1.98	.4761	.0239	2.48	.4934	.0066
1.99	.4767	.0233	2.49	.4936	.0064
2.00	.4772	.0228	2.50	.4938	.0062
2.01	.4778	.0222	2.51	.4940	.0060
2.02	.4783	.0217	2.52	.4941	.0059
2.03	.4788	.0212	2.53	.4943	.0057
2.04	.4793	.0207	2.54	.4945	.0055
2.05	.4798	.0202	2.55	.4946	.0054
2.06	.4803	.0197	2.56	.4948	.0052
2.07	.4808	.0192	2.57	.4949	.0051
2.08	.4812	.0188	2.58	.4951	.0049
2.09	.4817	.0183	2.59	.4952	.0048

$z_{cv} = 1.645$ for directional test, $\alpha = .05$

$z_{cv} = \pm 1.96$ for nondirectional test, $\alpha = .05$

$z_{cv} = \pm 2.58$ for nondirectional test, $\alpha = .01$

(continues)

TABLE A.1 Proportions of areas under the normal curve *(continued)*

z	Area between mean and z (A)	Area beyond z (B)	z	Area between mean and z (A)	Area beyond z (B)
2.60	.4953	.0047	3.00	.4987	.0013
2.61	.4955	.0045	3.01	.4987	.0013
2.62	.4956	.0044	3.02	.4987	.0013
2.63	.4957	.0043	3.03	.4988	.0012
2.64	.4959	.0041	3.04	.4988	.0012
2.65	.4960	.0040	3.05	.4989	.0011
2.66	.4961	.0039	3.06	.4989	.0011
2.67	.4962	.0038	3.07	.4989	.0011
2.68	.4963	.0037	3.08	.4990	.0010
2.69	.4964	.0036	3.09	.4990	.0010
2.70	.4965	.0035	3.10	.4990	.0010
2.71	.4966	.0034	3.11	.4991	.0009
2.72	.4967	.0033	3.12	.4991	.0009
2.73	.4968	.0032	3.13	.4991	.0009
2.74	.4969	.0031	3.14	.4992	.0008
2.75	.4970	.0030	3.15	.4992	.0008
2.76	.4971	.0029	3.16	.4992	.0008
2.77	.4972	.0028	3.17	.4992	.0008
2.78	.4973	.0027	3.18	.4993	.0007
2.79	.4974	.0026	3.19	.4993	.0007
2.80	.4974	.0026	3.20	.4993	.0007
2.81	.4975	.0025	3.21	.4993	.0007
2.82	.4976	.0024	3.22	.4994	.0006
2.83	.4977	.0023	3.23	.4994	.0006
2.84	.4977	.0023	3.24	.4994	.0006
2.85	.4978	.0022	3.25	.4994	.0006
2.86	.4979	.0021	3.30	.4995	.0005
2.87	.4979	.0021	3.35	.4996	.0004
2.88	.4980	.0020	3.40	.4997	.0003
2.89	.4981	.0019	3.45	.4997	.0003
2.90	.4981	.0019	3.50	.4998	.0002
2.91	.4982	.0018	3.60	.4998	.0002
2.92	.4982	.0018	3.70	.4999	.0001
2.93	.4983	.0017	3.80	.4999	.0001
2.94	.4984	.0016	3.90	.49995	.00005
2.95	.4984	.0016	4.00	.49997	.00003
2.96	.4985	.0015			
2.97	.4985	.0015			
2.98	.4986	.0014			
2.99	.4986	.0014			

Adapted from Table IIi of R. A. Fisher & F. Yates, *Statistical Tables for Biological, Agricultural, and Medical Research,* Sixth Edition, published by Longman Group UK, Ltd., (1974). Adapted with permission.

For your convenience, this table is reprinted on the inside back cover of the textbook.

TABLE A.2 Critical values of *t*

For a description in the text, see page 188.

AN EXAMPLE USING TABLE A.2

Assume $df = 12$, the level of significance $(\alpha) = .05$, and the test is nondirectional. If t_{obs} is greater than or equal to $t_{cv} = 2.179$, then t_{obs} is statistically significant.

	Level of significance (α) for directional (one-tailed) test			
	.05	**.025**	**.01**	**.005**
	Level of significance (α) for nondirectional (two-tailed) test			
$df = n - 1$	**.10**	**.05**	**.02**	**.01**
1	6.314	12.706	31.821	63.657
2	2.920	4.303	6.965	9.925
3	2.353	3.182	4.541	5.841
4	2.132	2.776	3.747	4.604
5	2.015	2.571	3.365	4.032
6	1.943	2.447	3.143	3.707
7	1.895	2.365	2.998	3.499
8	1.860	2.306	2.896	3.355
9	1.833	2.262	2.821	3.250
10	1.812	2.228	2.764	3.169
11	1.796	2.201	2.718	3.106
12	1.782	2.179	2.681	3.055
13	1.771	2.160	2.650	3.012
14	1.761	2.145	2.624	2.977
15	1.753	2.131	2.602	2.947
16	1.746	2.120	2.583	2.921
17	1.740	2.110	2.567	2.898
18	1.734	2.101	2.552	2.878
19	1.729	2.093	2.539	2.861
20	1.725	2.086	2.528	2.845
21	1.721	2.080	2.518	2.831
22	1.717	2.074	2.508	2.819
23	1.714	2.069	2.500	2.807
24	1.711	2.064	2.492	2.797
25	1.708	2.060	2.485	2.787
26	1.706	2.056	2.479	2.779
27	1.703	2.052	2.473	2.771
28	1.701	2.048	2.467	2.763
29	1.699	2.045	2.462	2.756
30	1.697	2.042	2.457	2.750
40	1.684	2.021	2.423	2.704
60	1.671	2.000	2.390	2.660
120	1.658	1.980	2.358	2.617
∞	1.645	1.960	2.326	2.576

When $df = \infty$, $t_{cv} = z_{cv}$

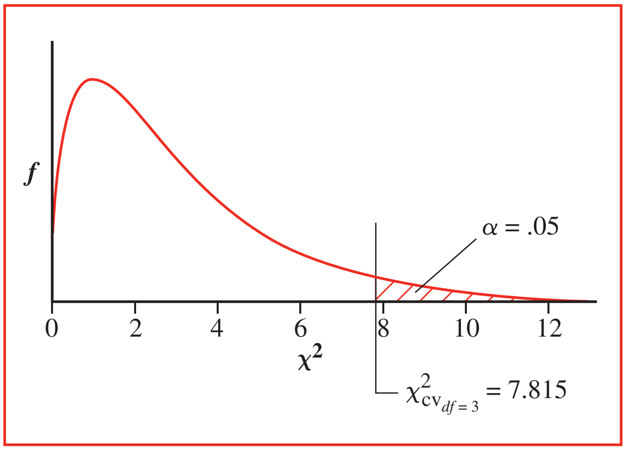
Adapted from Table III of R. A. Fisher & F. Yates, *Statistical Tables for Biological, Agricultural, and Medical Research.* Sixth Edition, published by Longman Group UK, Ltd., (1974). Adapted with permission.

TABLE A.3 Critical values of χ^2

For a description in the text, see page 504.

AN EXAMPLE USING TABLE A.3

Assume $df = 3$ and $\alpha = .05$. The critical value of χ^2 that leaves .05 in the right-hand tail is $\chi^2_{cv} = 7.815$. χ^2_{obs} is statistically significant if it is greater than or equal to χ^2_{cv}.



The critical value of χ^2 with $df = 3$ is 7.815

df	Level of significance (α) .05	.01
1	3.841	6.635
2	5.991	9.210
3	7.815	11.345
4	9.488	13.277
5	11.070	15.086
6	12.592	16.812
7	14.067	18.475
8	15.507	20.090
9	16.919	21.666
10	18.307	23.209
11	19.675	24.725
12	21.026	26.217
13	22.362	27.688
14	23.685	29.141
15	24.996	30.578
16	26.296	32.000
17	27.587	33.409
18	28.869	34.805
19	30.144	36.191
20	31.410	37.566
21	32.671	38.932
22	33.924	40.289
23	35.172	41.638
24	36.415	42.980
25	37.652	44.314
26	38.885	45.642
27	40.113	46.963
28	41.337	48.278
29	42.557	49.588
30	43.773	50.892
> 30 See note at left		

Adapted from Table IV of R. A. Fisher & F. Yates, *Statistical Tables for Biological, Agricultural, and Medical Reseach,* Sixth Edition, published by Longman Group UK, Ltd., (1974). Adapted with permission.

If $df > 30$, then χ^2_{cv} can be approximated by using the normal distribution:

$$\chi^2_{cv} = \frac{z^2_{cv}}{2} + \sqrt{2df - 1} + \frac{2df - 1}{2}$$

where z_{cv} is obtained from Table A.1. Note that in order to obtain directional χ^2_{cv} values (as are shown in Table A.3), one must also use directional z_{cv} values from Table A.l.

Some algebra will show that the preceding expression is equivalent to the more frequently seen expression

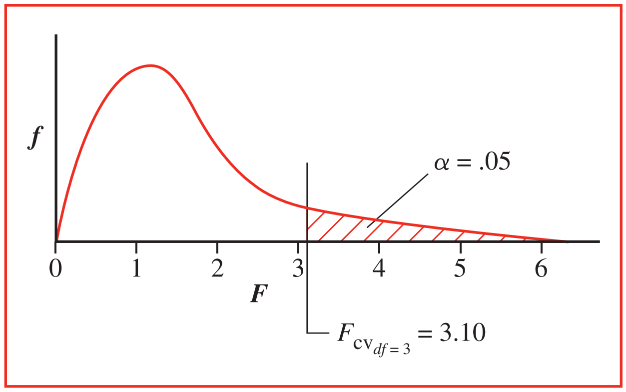
$$z = \sqrt{2\chi^2} - \sqrt{2df - 1}$$

TABLE A.4 Critical values of F: $\alpha = .05$

For a description in the text, see page 364.

AN EXAMPLE USING TABLE A.4

Assume that the numerator of F has $df = 3$ and the denominator has $df = 20$, and $\alpha = .05$. The critical value of F that leaves .05 in the right-hand tail is $F_{cv_{3,20}} = 3.10$. F_{obs} is statistically significant if it is greater than or equal to F_{cv}.



Numerator $df = 3$; denominator $df = 20$; $\alpha = .05$; $F_{cv_{3,20}} = 3.10$

df for denominator	Level of significance (α) = .05 *df* for numerator									
	1	2	3	4	5	6	10	30	120	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	241.9	250.1	253.3	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.40	19.46	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.79	8.62	8.55	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	5.96	5.75	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.74	4.50	4.40	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.06	3.81	3.70	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.64	3.38	3.27	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.35	3.08	2.97	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.14	2.86	2.75	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	2.98	2.70	2.58	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	2.85	2.57	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.75	2.47	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.67	2.38	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.60	2.10	2.18	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.54	2.25	2.11	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.49	2.19	2.06	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.45	2.15	2.01	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.41	2.11	1.97	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.38	2.07	1.93	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.35	2.04	1.90	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.32	2.01	1.87	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.30	1.98	1.84	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.27	1.96	1.81	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.25	1.94	1.79	1.73
25	4.24	3.39	2.99	2.76	2.60	2.49	2.24	1.92	1.77	1.71
26	4.23	3.37	2.98	2.74	2.59	2.47	2.22	1.90	1.75	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.20	1.88	1.73	1.67
28	4.20	3.34	2.95	2.71	2.56	2.45	2.19	1.87	1.71	1.65
29	4.18	3.33	2.93	2.70	2.55	2.43	2.18	1.85	1.70	1.64
30	4.17	3.32	2.92	2.69	2.53	2.42	2.16	1.84	1.68	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.08	1.74	1.58	1.51
60	4.00	3.15	2.76	2.53	2.37	2.25	1.99	1.65	1.47	1.39
120	3.92	3.07	2.68	2.45	2.29	2.17	1.91	1.55	1.35	1.25
∞	3.84	3.00	2.60	2.37	2.21	2.10	1.83	1.46	1.22	1.00

(continues)

TABLE A.4 Critical values of *F (continued):* $\alpha = .01$

df for denominator	Level of significance (α) = .01 *df* for numerator									
	1	**2**	**3**	**4**	**5**	**6**	**10**	**30**	**120**	**∞**
1	4052	4999.5	5403	5625	5764	5859	6056	6261	6339	6366
2	98.50	99.00	99.17	99.25	99.30	99.33	99.40	99.47	99.49	99.50
3	34.12	30.82	29.46	28.71	28.24	27.91	27.23	26.50	26.22	26.13
4	21.20	18.00	16.69	15.98	15.52	15.21	14.55	13.84	13.56	13.46
5	16.26	13.27	12.06	11.39	10.97	10.67	10.05	9.38	9.11	9.02
6	13.75	10.92	9.78	9.15	8.75	8.47	7.87	7.23	6.97	6.88
7	12.25	9.55	8.45	7.85	7.46	7.19	6.62	5.99	5.74	5.65
8	11.26	8.65	7.59	7.01	6.63	6.37	5.81	5.20	4.95	4.86
9	10.56	8.02	6.99	6.42	6.06	5.80	5.26	4.65	4.40	4.31
10	10.04	7.56	6.55	5.99	5.64	5.39	4.85	4.25	4.00	3.91
11	9.65	7.21	6.22	5.67	5.32	5.07	4.54	3.94	3.69	3.60
12	9.33	6.93	5.95	5.41	5.06	4.82	4.30	3.70	3.45	3.36
13	9.07	6.70	5.74	5.21	4.86	4.62	4.10	3.51	3.25	3.17
14	8.86	6.51	5.56	5.04	4.69	4.46	3.94	3.35	3.09	3.00
15	8.68	6.36	5.42	4.89	4.56	4.32	3.80	3.21	2.96	2.87
16	8.53	6.23	5.29	4.77	4.44	4.20	3.69	3.10	2.84	2.75
17	8.40	6.11	5.18	4.67	4.34	4.10	3.59	3.00	2.75	2.65
18	8.29	6.01	5.09	4.58	4.25	4.01	3.51	2.92	2.66	2.57
19	8.18	5.93	5.01	4.50	4.17	3.94	3.43	2.84	2.58	2.49
20	8.10	5.85	4.94	4.43	4.10	3.87	3.37	2.78	2.52	2.42
21	8.02	5.78	4.87	4.37	4.04	3.81	3.31	2.72	2.46	2.36
22	7.95	5.72	4.82	4.31	3.99	3.76	3.26	2.67	2.40	2.31
23	7.88	5.66	4.76	4.26	3.94	3.71	3.21	2.62	2.35	2.26
24	7.82	5.61	4.72	4.22	3.90	3.67	3.17	2.58	2.31	2.21
25	7.77	5.57	4.68	4.18	3.85	3.63	3.13	2.54	2.27	2.17
26	7.72	5.53	4.64	4.14	3.82	3.59	3.09	2.50	2.23	2.13
27	7.68	5.49	4.60	4.11	3.78	3.56	3.06	2.47	2.20	2.10
28	7.64	5.45	4.57	4.07	3.75	3.53	3.03	2.44	2.17	2.06
29	7.60	5.42	4.54	4.04	3.73	3.50	3.00	2.41	2.14	2.03
30	7.56	5.39	4.51	4.02	3.70	3.47	2.98	2.39	2.11	2.01
40	7.31	5.18	4.31	3.83	3.51	3.29	2.80	2.20	1.92	1.80
60	7.08	4.98	4.13	3.65	3.34	3.12	2.63	2.03	1.73	1.60
120	6.85	4.79	3.95	3.48	3.17	2.96	2.47	1.86	1.53	1.38
∞	6.63	4.61	3.78	3.32	3.02	2.80	2.32	1.70	1.32	1.00

TABLE A.5 Critical values of *Q*, the Studentized range statistic: $\alpha = .05$

For a description, see **Resource 15A,** page 2.

AN EXAMPLE USING TABLE A.5

If there are $k = 4$ groups, the *df* within cells is 24, and $\alpha = .05$, then Q_{obs} is significant if it is greater than or equal to $Q_{cv} = 3.90$.

	Level of significance (α) = .05 *k* = the number of means or number of steps between ordered means											
df_w	2	3	4	5	6	7	8	9	10	12	15	20
1	17.97	26.98	32.82	37.08	40.41	43.12	45.40	47.36	49.07	51.96	55.36	59.56
2	6.08	8.33	9.80	10.88	11.74	12.44	13.03	13.54	13.99	14.75	15.65	16.77
3	4.50	5.91	6.82	7.50	8.04	8.48	8.85	9.18	9.46	9.95	10.52	11.24
4	3.93	5.04	5.76	6.29	6.71	7.05	7.35	7.60	7.83	8.21	8.66	9.23
5	3.64	4.60	5.22	5.67	6.03	6.33	6.58	6.80	6.99	7.32	7.72	8.21
6	3.46	4.34	4.90	5.30	5.63	5.90	6.12	6.32	6.49	6.79	7.14	7.59
7	3.34	4.16	4.68	5.06	5.36	5.61	5.82	6.00	6.16	6.43	6.76	7.17
8	3.26	4.04	4.53	4.89	5.17	5.40	5.60	5.77	5.92	6.18	6.48	6.87
9	3.20	3.95	4.41	4.76	5.02	5.24	5.43	5.59	5.74	5.98	6.28	6.64
10	3.15	3.88	4.33	4.65	4.91	5.12	5.30	5.46	5.60	5.83	6.11	6.47
11	3.11	3.82	4.26	4.57	4.82	5.03	5.20	5.35	5.49	5.71	5.98	6.33
12	3.08	3.77	4.20	4.51	4.75	4.95	5.12	5.27	5.39	5.61	5.88	6.21
13	3.06	3.73	4.15	4.45	4.69	4.88	5.05	5.19	5.32	5.53	5.79	6.11
14	3.03	3.70	4.11	4.41	4.64	4.83	4.99	5.13	5.25	5.46	5.71	6.03
15	3.01	3.67	4.08	4.37	4.59	4.78	4.94	5.08	5.20	5.40	5.65	5.96
16	3.00	3.65	4.05	4.33	4.56	4.74	4.90	5.03	5.15	5.35	5.59	5.90
17	2.98	3.63	4.02	4.30	4.52	4.70	4.86	4.99	5.11	5.31	5.54	5.84
18	2.97	3.61	4.00	4.28	4.49	4.67	4.82	4.96	5.07	5.27	5.50	5.79
19	2.96	3.59	3.98	4.25	4.47	4.65	4.79	4.92	5.04	5.23	5.46	5.75
20	2.95	3.58	3.96	4.23	4.45	4.62	4.77	4.90	5.01	5.20	5.43	5.71
24	2.92	3.53	3.90	4.17	4.37	4.54	4.68	4.81	4.92	5.10	5.32	5.59
30	2.89	3.49	3.85	4.10	4.30	4.46	4.60	4.72	4.82	5.00	5.21	5.47
40	2.86	3.44	3.79	4.04	4.23	4.39	4.52	4.63	4.73	4.90	5.11	5.36
60	2.83	3.40	3.74	3.98	4.16	4.31	4.44	4.55	4.65	4.81	5.00	5.24
120	2.80	3.36	3.68	3.92	4.10	4.24	4.36	4.47	4.56	4.71	4.90	5.13
∞	2.77	3.31	3.63	3.86	4.03	4.17	4.29	4.39	4.47	4.62	4.80	5.01

(continues)

TABLE A.5 Critical values of *Q*, the Studentized range statistic *(continued):* $\alpha = .05$

	Level of significance (α) = .01 *k* = the number of means or number of steps between ordered means											
df_W	2	3	4	5	6	7	8	9	10	12	15	20
1	90.03	135.0	164.3	185.6	202.2	215.8	227.2	237.0	245.6	260.0	277.0	298.0
2	14.04	19.02	22.29	24.72	26.63	28.20	29.53	30.68	31.69	33.40	35.43	37.95
3	8.26	10.62	12.17	13.33	14.24	15.00	15.64	16.20	16.69	17.53	18.52	19.77
4	6.51	8.12	9.17	9.96	10.58	11.10	11.55	11.93	12.27	12.84	13.53	14.40
5	5.70	6.98	7.80	8.42	8.91	9.32	9.67	9.97	10.24	10.70	11.24	11.93
6	5.24	6.33	7.03	7.56	7.97	8.32	8.61	8.87	9.10	9.48	9.95	10.54
7	4.95	5.92	6.54	7.01	7.37	7.68	7.94	8.17	8.37	8.71	9.12	9.65
8	4.75	5.64	6.20	6.62	6.96	7.24	7.47	7.68	7.86	8.18	8.55	9.03
9	4.60	5.43	5.96	6.35	6.66	6.91	7.13	7.33	7.49	7.78	8.13	8.57
10	4.48	5.27	5.77	6.14	6.43	6.67	6.87	7.05	7.21	7.49	7.81	8.23
11	4.39	5.15	5.62	5.97	6.25	6.48	6.67	6.84	6.99	7.25	7.56	7.95
12	4.32	5.05	5.50	5.84	6.10	6.32	6.51	6.67	6.81	7.06	7.36	7.73
13	4.26	4.96	5.40	5.73	5.98	6.19	6.37	6.53	6.67	6.90	7.19	7.55
14	4.21	4.89	5.32	5.63	5.88	6.08	6.26	6.41	6.54	6.77	7.05	7.39
15	4.17	4.84	5.25	5.56	5.80	5.99	6.16	6.31	6.44	6.66	6.93	7.26
16	4.13	4.79	5.19	5.49	5.72	5.92	6.08	6.22	6.35	6.56	6.82	7.15
17	4.10	4.74	5.14	5.43	5.66	5.85	6.01	6.15	6.27	6.48	6.73	7.05
18	4.07	4.70	5.09	5.38	5.60	5.79	5.94	6.08	6.20	6.41	6.65	6.97
19	4.05	4.67	5.05	5.33	5.55	5.73	5.89	6.02	6.14	6.34	6.58	6.89
20	4.02	4.64	5.02	5.29	5.51	5.69	5.84	5.97	6.09	6.28	6.52	6.82
24	3.96	4.55	4.91	5.17	5.37	5.54	5.69	5.81	5.92	6.11	6.33	6.61
30	3.89	4.45	4.80	5.05	5.24	5.40	5.54	5.65	5.76	5.93	6.14	6.41
40	3.82	4.37	4.70	4.93	5.11	5.26	5.39	5.50	5.60	5.76	5.96	6.21
60	3.76	4.28	4.59	4.82	4.99	5.13	5.25	5.36	5.45	5.60	5.78	6.01
120	3.70	4.20	4.50	4.71	4.87	5.01	5.12	5.21	5.30	5.44	5.61	5.83
∞	3.64	4.12	4.40	4.60	4.76	4.88	4.99	5.08	5.16	5.29	5.45	5.65

TABLE A.6 Critical values of the Mann–Whitney *U*: $\alpha = .05$

Directional (one-tailed) values are shown in lightface type; nondirectional (two-tailed) values are shown in **boldface** type. For a description in the text, see page 516. Dashes (—) indicate no decision is possible.

AN EXAMPLE USING TABLE A.6

If there are 8 observations in the first group ($n_1 = 8$) and 12 observations in the second group ($n_2 = 12$), and $\alpha = .05$, nondirectional, then $U_{cv} = 26$. U_{obs} is statistically significant if it is less than or equal to U_{cv}.

n_2, number of observations in second group	n_1, number of observations in first group																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	0	0	0	1	1	1	1	2	2	2	3	3	3	4	4	4
	—	—	—	—	—	—	—	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**
3	—	—	0	0	1	2	2	3	3	4	5	5	6	7	7	8	9	9	10	11
	—	—	—	—	**0**	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**5**	**6**	**6**	**7**	**7**	**8**
4	—	—	0	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18
	—	—	—	**0**	**1**	**2**	**3**	**4**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**11**	**12**	**13**	**13**
5	—	0	1	2	4	5	6	8	9	11	12	13	15	16	18	19	20	22	23	25
	—	—	**0**	**1**	**2**	**3**	**5**	**6**	**7**	**8**	**9**	**11**	**12**	**13**	**14**	**15**	**17**	**18**	**19**	**20**
6	—	0	2	3	5	7	8	10	12	14	16	17	19	21	23	25	26	28	30	32
	—	—	**1**	**2**	**3**	**5**	**6**	**8**	**10**	**11**	**13**	**14**	**16**	**17**	**19**	**21**	**22**	**24**	**25**	**27**
7	—	0	2	4	6	8	11	13	15	17	19	21	24	26	28	30	33	35	37	39
	—	—	**1**	**3**	**5**	**6**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**	**32**	**34**
8	—	1	3	5	8	10	13	15	18	20	23	26	28	31	33	36	39	41	44	47
	—	**0**	**2**	**4**	**6**	**8**	**10**	**13**	**15**	**17**	**19**	**22**	**24**	**26**	**29**	**31**	**34**	**36**	**38**	**41**
9	—	1	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54
	—	**0**	**2**	**4**	**7**	**10**	**12**	**15**	**17**	**20**	**23**	**26**	**28**	**31**	**34**	**37**	**39**	**42**	**45**	**48**
10	—	1	4	7	11	14	17	20	24	27	31	34	37	41	44	48	51	55	58	62
	—	**0**	**3**	**5**	**8**	**11**	**14**	**17**	**20**	**23**	**26**	**29**	**33**	**36**	**39**	**42**	**45**	**48**	**52**	**55**
11	—	1	5	8	12	16	19	23	27	31	34	38	42	46	50	54	57	61	65	69
	—	**0**	**3**	**6**	**9**	**13**	**16**	**19**	**23**	**26**	**30**	**33**	**37**	**40**	**44**	**47**	**51**	**55**	**58**	**62**
12	—	2	5	9	13	17	21	26	30	34	38	42	47	51	55	60	64	68	72	77
	—	**1**	**4**	**7**	**11**	**14**	**18**	**22**	**26**	**29**	**33**	**37**	**41**	**45**	**49**	**53**	**57**	**61**	**65**	**69**
13	—	2	6	10	15	19	24	28	33	37	42	47	51	56	61	65	70	75	80	84
	—	**1**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**33**	**37**	**41**	**45**	**50**	**54**	**59**	**63**	**67**	**72**	**76**
14	—	2	7	11	16	21	26	31	36	41	46	51	56	61	66	71	77	82	87	92
	—	**1**	**5**	**9**	**13**	**17**	**22**	**26**	**31**	**36**	**40**	**45**	**50**	**55**	**59**	**64**	**67**	**74**	**78**	**83**
15	—	3	7	12	18	23	28	33	39	44	50	55	61	66	72	77	83	88	94	100
	—	**1**	**5**	**10**	**14**	**19**	**24**	**29**	**34**	**39**	**44**	**49**	**54**	**59**	**64**	**70**	**75**	**80**	**85**	**90**
16	—	3	8	14	19	25	30	36	42	48	54	60	65	71	77	83	89	95	101	107
	—	**1**	**6**	**11**	**15**	**21**	**26**	**31**	**37**	**42**	**47**	**53**	**59**	**64**	**70**	**75**	**81**	**86**	**92**	**98**
17	—	3	9	15	20	26	33	39	45	51	57	64	70	77	83	89	96	102	109	115
	—	**2**	**6**	**11**	**17**	**22**	**28**	**34**	**39**	**45**	**51**	**57**	**63**	**67**	**75**	**81**	**87**	**93**	**99**	**105**
18	—	4	9	16	22	28	35	41	48	55	61	68	75	82	88	95	102	109	116	123
	—	**2**	**7**	**12**	**18**	**24**	**30**	**36**	**42**	**48**	**55**	**61**	**67**	**74**	**80**	**86**	**93**	**99**	**106**	**112**
19	0	4	10	17	23	30	37	44	51	58	65	72	80	87	94	101	109	116	123	130
	—	**2**	**7**	**13**	**19**	**25**	**32**	**38**	**45**	**52**	**58**	**65**	**72**	**78**	**85**	**92**	**99**	**106**	**113**	**119**
20	0	4	11	18	25	32	39	47	54	62	69	77	84	92	100	107	115	123	130	138
	—	**2**	**8**	**13**	**20**	**27**	**34**	**41**	**48**	**55**	**62**	**69**	**76**	**83**	**90**	**98**	**105**	**112**	**119**	**127**

(continues)

TABLE A.6 Critical values of the Mann–Whitney U ($\alpha = .05$) (continued)

n_2, number of observations in second group	n_1, number of observations in first group																			
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0	0	0	0	1	1
	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	**0**	**0**
3	—	—	—	—	—	—	0	0	1	1	1	2	2	2	3	3	4	4	4	5
	—	—	—	—	—	—	—	—	**0**	**0**	**0**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**3**	**3**
4	—	—	—	—	0	1	1	2	3	3	4	5	5	6	7	7	8	9	9	10
	—	—	—	—	—	**0**	**0**	**1**	**1**	**2**	**2**	**3**	**3**	**4**	**5**	**5**	**6**	**6**	**7**	**8**
5	—	—	—	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	—	—	—	—	**0**	**1**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
6	—	—	—	1	2	3	4	6	7	8	9	11	12	13	15	16	18	19	20	22
	—	—	—	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**9**	**10**	**11**	**12**	**13**	**15**	**16**	**17**	**18**
7	—	—	0	1	3	4	6	7	9	11	12	14	16	17	19	21	23	24	26	28
	—	—	—	**0**	**1**	**3**	**4**	**6**	**7**	**9**	**10**	**12**	**13**	**15**	**16**	**18**	**19**	**21**	**22**	**24**
8	—	—	0	2	4	6	7	9	11	13	15	17	20	22	24	26	28	30	32	34
	—	—	—	**1**	**2**	**4**	**6**	**7**	**9**	**11**	**13**	**15**	**17**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
9	—	—	1	3	5	7	9	11	14	16	18	21	23	26	28	31	33	36	38	40
	—	—	**0**	**1**	**3**	**5**	**7**	**9**	**11**	**13**	**16**	**18**	**20**	**22**	**24**	**27**	**29**	**31**	**33**	**36**
10	—	—	1	3	6	8	11	13	16	19	22	24	27	30	33	36	38	41	44	47
	—	—	**0**	**2**	**4**	**6**	**9**	**11**	**13**	**16**	**18**	**21**	**24**	**26**	**29**	**31**	**34**	**37**	**39**	**42**
11	—	—	1	4	7	9	12	15	18	22	25	28	31	34	37	41	44	47	50	53
	—	—	**0**	**2**	**5**	**7**	**10**	**13**	**16**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**
12	—	—	2	5	8	11	14	17	21	24	28	31	35	38	42	46	49	53	56	60
	—	—	**1**	**3**	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**31**	**34**	**37**	**41**	**44**	**47**	**51**	**54**
13	—	0	2	5	9	12	16	20	23	27	31	35	39	43	47	51	55	59	63	67
	—	—	**1**	**3**	**7**	**10**	**13**	**17**	**20**	**24**	**27**	**31**	**34**	**38**	**42**	**45**	**49**	**53**	**56**	**60**
14	—	0	2	6	10	13	17	22	26	30	34	38	43	47	51	56	60	65	69	73
	—	—	**1**	**4**	**7**	**11**	**15**	**18**	**22**	**26**	**30**	**34**	**38**	**42**	**46**	**50**	**54**	**58**	**63**	**67**
15	—	0	3	7	11	15	19	24	28	33	37	42	47	51	56	61	66	70	75	80
	—	—	**2**	**5**	**8**	**12**	**16**	**20**	**24**	**29**	**33**	**37**	**42**	**46**	**51**	**55**	**60**	**64**	**69**	**73**
16	—	0	3	7	12	16	21	26	31	36	41	46	51	56	61	66	71	76	82	87
	—	—	**2**	**5**	**9**	**13**	**18**	**22**	**27**	**31**	**36**	**41**	**45**	**50**	**55**	**60**	**65**	**70**	**74**	**79**
17	—	0	4	8	13	18	23	28	33	38	44	49	55	60	66	71	77	82	88	93
	—	—	**2**	**6**	**10**	**15**	**19**	**24**	**29**	**34**	**39**	**44**	**49**	**54**	**60**	**65**	**70**	**75**	**81**	**86**
18	—	0	4	9	14	19	24	30	36	41	47	53	59	65	70	76	82	88	94	100
	—	—	**2**	**6**	**11**	**16**	**21**	**26**	**31**	**37**	**4**	**47**	**53**	**58**	**64**	**70**	**75**	**81**	**87**	**92**
19	—	1	4	9	15	20	26	32	38	44	50	56	63	69	75	82	88	94	101	107
	—	**0**	**3**	**7**	**12**	**17**	**22**	**28**	**33**	**39**	**45**	**51**	**56**	**63**	**69**	**74**	**81**	**87**	**93**	**99**
20	—	1	5	10	16	22	28	34	40	47	53	60	67	73	80	87	93	100	107	114
	—	**0**	**3**	**8**	**13**	**18**	**24**	**30**	**36**	**42**	**48**	**54**	**60**	**67**	**73**	**79**	**86**	**92**	**99**	**105**

Based on *Introductory Statistics,* by R. E. Kirk, Brooks/Cole, 1984.

For a description in the text, see page 518.

AN EXAMPLE USING TABLE A.7

T is the smaller sum of ranks associated with differences that all have the same sign. If there are 20 pairs of differences (n = 20), α = .05, and the test is nondirectional, then T_{cv} = 52. T_{obs} is statistically significant if it is *less than* or equl to T_{cv}.

TABLE A.7 Critical values of Wilcoxon's *T*

	Level of significance (α) for directional (one-tailed) test			
	.05	.025	.01	.005
	Level of significance (α) for nondirectional (two-tailed) test			
n	.10	.05	.02	.01
5	0	—	—	—
6	2	0	—	—
7	3	2	0	—
8	5	3	1	0
9	8	5	3	1
10	10	8	5	3
11	13	10	7	5
12	17	13	9	7
13	21	17	12	9
14	25	21	15	12
15	30	25	19	15
16	35	29	23	19
17	41	34	27	23
18	47	40	32	27
19	53	46	37	32
20	60	52	43	37
21	67	58	49	42
22	75	65	55	48
23	83	73	62	54
24	91	81	69	61
25	100	89	76	68
26	110	98	84	75
27	119	107	92	83
28	130	116	101	91
29	140	126	110	100
30	151	137	120	109
31	163	147	130	118
32	175	159	140	128
33	187	170	151	138
34	200	182	162	148
35	213	195	173	159
36	227	208	185	171
37	241	221	198	182
38	256	235	211	194
39	271	249	224	207
40	286	264	238	220
41	302	279	252	233
42	319	294	266	247
43	336	310	281	261
44	353	327	296	276
45	371	343	312	291
46	389	361	328	307
47	407	378	345	322
48	426	396	362	339
49	446	415	379	355
50	466	434	397	373

TABLE A.8 Critical values of *r*, the Pearson product-moment correlation coefficient

For a description in the text, see page 441.

AN EXAMPLE USING TABLE A.8

If we let $\alpha = .05$, the test is nondirectional, and there are $n = 20$ pairs of scores, then $df = n - 2 = 18$. Then the critical value of Pearson's $r_{cv} = \pm.4438$. If r_{obs} is greater than or equal to (in absolute value) r_{cv}, then r_{obs} is statistically significant.

For correlation, $df = n - 2$

	Level of significance (α) for directional (one-tailed) test			
	.05	.025	.01	.005
	Level of significance (α) for nondirectional (two-tailed) test			
***df* = *n* − 2**	**.10**	**.05**	**.02**	**.01**
1	.98769	.99692	.999507	.999877
2	.90000	.95000	.98000	.990000
3	.8054	.8783	.93433	.95873
4	.7293	.8114	.8822	.91720
5	.6694	.7545	.8329	.8745
6	.6215	.7067	.7887	.8343
7	.5822	.6664	.7498	.7977
8	.5494	.6319	.7155	.7646
9	.5214	.6021	.6851	.7348
10	.4973	.5760	.6581	.7079
11	.4762	.5529	.6339	.6835
12	.4575	.5324	.6120	.6614
13	.4409	.5139	.5923	.6411
14	.4259	.4973	.5742	.6226
15	.4124	.4821	.5577	.6055
16	.4000	.4683	.5425	.5897
17	.3887	.4555	.5285	.5751
18	.3783	.4438	.5155	.5614
19	.3687	.4329	.5034	.5487
20	.3598	.4227	.4921	.5368
25	.3233	.3809	.4451	.4869
30	.2960	.3494	.4093	.4487
35	.2746	.3246	.3810	.4182
40	.2573	.3044	.3578	.3932
45	.2428	.2875	.3384	.3721
50	.2306	.2732	.3218	.3541
60	.2108	.2500	.2948	.3248
70	.1954	.2319	.2737	.3017
80	.1829	.2172	.2565	.2830
90	.1726	.2050	.2422	.2673
100	.1638	.1946	.2301	.2540

Adapted from Table VII of R. A. Fisher & F. Yates, *Statistical Tables for Biological, Agricultural, and Medical Research,* Sixth Edition, published by Longman Group UK, Ltd., (1974). Adapted with permission.

TABLE A.9 Critical values of r_S, the Spearman rank-order correlation coefficient

For a description in the text, see page 446.

AN EXAMPLE USING TABLE A.9

If we let $\alpha = .05$, the test is nondirectional, and there are $n = 20$ pairs of scores, then $r_{S_{cv}} = \pm.450$. If $r_{S_{obs}}$ is greater than or equal to (in absolute value) $r_{S_{cv}}$, then $r_{S_{obs}}$ is statistically significant.

	Level of significance (α) for directional (one-tailed) test			
	.05	.025	.01	.005
	Level of significance (α) for nondirectional (two-tailed) test			
n	.10	.05	.02	.01
5	.900	—	—	—
6	.829	.886	.943	—
7	.714	.786	.893	.929
8	.643	.738	.833	.881
9	.600	.700	.783	.833
10	.564	.648	.745	.794
11	.536	.618	.709	.818
12	.497	.591	.703	.780
13	.475	.566	.673	.745
14	.457	.545	.646	.716
15	.441	.525	.623	.689
16	.425	.507	.601	.666
17	.412	.490	.582	.645
18	.399	.476	.564	.625
19	.388	.462	.549	.608
20	.377	.450	.534	.591
21	.368	.438	.521	.576
22	.359	.428	.508	.562
23	.351	.418	.496	.549
24	.343	.409	.485	.537
25	.336	.400	.475	.526
26	.329	.392	.465	.515
27	.323	.385	.456	.505
28	.317	.377	.448	.496
29	.311	.370	.440	.487
30	.305	.364	.432	.478

TABLE A.10 2000 Random digits

For a description in the text, see page 153.

AN EXAMPLE USING TABLE A.10

A “seed” digit is chosen by some quasi-random procedure (such as closing your eyes and pointing at the page). The digits immediately following the seed are a random sequence.

	1	6	11	16	21	26	31	36	41	46
1	10480	15011	01536	02011	81647	91646	69179	14194	62590	36207
2	22368	46573	25595	85393	30995	89198	27982	53402	93965	34095
3	24130	48360	22527	97265	76393	64809	15179	24830	49340	32081
4	42167	93093	06243	61680	07856	16376	39440	53537	71341	57004
5	37570	39975	81837	16656	06121	91782	60468	81305	49684	60672
6	77921	06907	11008	42751	27756	53498	18602	70659	90655	15053
7	99562	72905	56420	69994	98872	31016	71194	18738	44013	48840
8	93601	91977	05463	07972	18876	20922	94595	56869	69014	60045
9	89579	14342	63661	10281	17453	18103	57740	84378	25331	12566
10	85475	36857	43342	53988	53060	59533	38867	62300	08158	17983
11	28918	69578	88231	33276	70997	79936	56865	05859	90106	31595
12	63553	40961	48235	03427	49626	69445	18663	72695	52180	20847
13	09429	93969	52636	92737	88974	33488	36320	17617	30015	08272
14	10365	61129	87529	85689	48237	52267	67689	93394	01511	26358
15	07119	97336	71048	08178	77233	13916	47564	81056	97735	85977
16	51085	12765	51821	51259	77452	16308	60756	92144	49442	53900
17	02368	21382	52404	60268	89368	19885	55322	44819	01188	65255
18	01011	54092	33362	94904	31273	04146	18594	29852	71585	85030
19	52162	53916	46369	58586	23216	14513	83149	98736	23495	64350
20	07056	97628	33787	09998	42698	06691	76988	13602	51851	46104
21	48663	91245	85828	14346	09172	30168	90229	04734	59193	22178
22	54164	58492	22421	74103	47070	25306	76468	26384	58151	06646
23	32639	32363	05597	24200	13363	38005	94342	28728	35806	06912
24	29334	27001	87637	87308	58731	00256	45834	15398	46557	41135
25	02488	33062	28834	07351	19731	92420	60952	61280	50001	67658
26	81525	72295	04839	96423	24878	82651	66566	14788	76797	14780
27	29676	20591	68086	26432	46901	20849	89768	81536	86645	12659
28	00742	57392	39064	66432	84673	40027	32832	61362	98947	96067
29	05366	04213	25669	26422	44407	44048	37937	63904	45766	66134
30	91921	26418	64117	94305	26766	25940	39972	22209	71500	64568
31	00582	04711	87917	77341	42206	35126	74087	99547	81817	42607
32	00725	69884	62797	56170	86324	88072	76222	36086	84637	93161
33	69011	65797	95876	55293	18988	27354	26575	08625	40801	59920
34	25976	57948	29888	88604	67917	48708	18912	82271	65424	69774
35	09763	83473	73577	12908	30883	18317	28290	35797	05998	41688
36	91567	42595	37958	30134	04024	86385	29880	99730	55536	84855
37	17955	56349	90999	49127	20044	59931	06115	20542	18059	02008
38	46503	18584	18845	49618	02304	51038	20655	58727	28168	15475
39	92157	89634	94824	78171	84610	82834	09922	25417	44137	48413
40	14577	62765	35605	81263	39667	47358	56873	56307	61607	49518