Exercise 8: An Introduction to Descriptive and Nonparametric Statistics

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Goals of this lab

1. To understand why statistics are used
2. To become familiar with descriptive statistics
1. To become familiar with nonparametric statistical tests, how to conduct them, and how to choose among them
2. To apply this knowledge to sample research questions

Background

If we are very fortunate, our experiments yield perfect data: all the animals in one treatment group behave one way, and all the animals in another treatment group behave another way. Usually our results are not so clear. In addition, even if we do get results that seem definitive, there is always a possibility that they are a result of chance.

Statistics enable us to objectively evaluate our results. Descriptive statistics are useful for exploring, summarizing, and presenting data. Inferential statistics are used for interpreting data and drawing conclusions about our hypotheses.

Descriptive statistics include the mean (average of all of the observations; see Table 8.1), mode (most frequent data class), and median (middle value in an ordered set of data). The variance, standard deviation, and standard error are measures of deviation from the mean (see Table 8.1). These statistics can be used to explore your data before going on to inferential statistics, when appropriate.

In hypothesis testing, a variety of statistical tests can be used to determine if the data best fit our null hypothesis (a statement of no difference) or an alternative hypothesis. More specifically, we attempt to reject one of these hypotheses. We calculate the test statistic appropriate for our research methods and the design of our study, and calculate the probability that the pattern we see in our data is due to chance alone. This probability is called the P value. By convention, most behavioral ecologists agree that when P is equal to or less than 0.05, we can confidently reject the null hypothesis.

To determine which type of statistical test to use on a given set of data, we must first determine whether or not the data fit a normal (bell-shaped) distribution. If so, we can use parametric statistical tests (see Figure 8.1). If the data are not normal, we must use nonparametric tests. Since many of the data collected in animal behavior studies are not normally distributed, we will focus on nonparametric tests in this lab.

A flow chart to help you decide which tests to use is given in Figure 8.1. Following this is a series of worked examples for a number of nonparametric tests. Begin by acquainting yourself with the flow chart; then skip ahead to the Methods section that follows the worked examples.

Here are some helpful terms:

Continuous data: numerical data, such as number of seconds, distance, or frequency of a behavior.

Categorical data: data that can be put into categories, such as number of animals that moved toward a stimulus, moved away from a stimulus, or stayed in place.

Ordinal data: categorical data where there is a logical ordering to the categories. A good example is the Likert scale that you see on many surveys: 1=Strongly disagree; 2=Disagree; 3=Neutral; 4=Agree; 5=Strongly agree.

Unpaired data: data points that are independent from each other, such as data generated by testing two separate groups of animals.

Paired data: data points that are naturally paired in some way, most commonly because the same animal was tested more than once. These data points should not be treated as independent from one another.

Number of groups: the number of different test groups being compared.

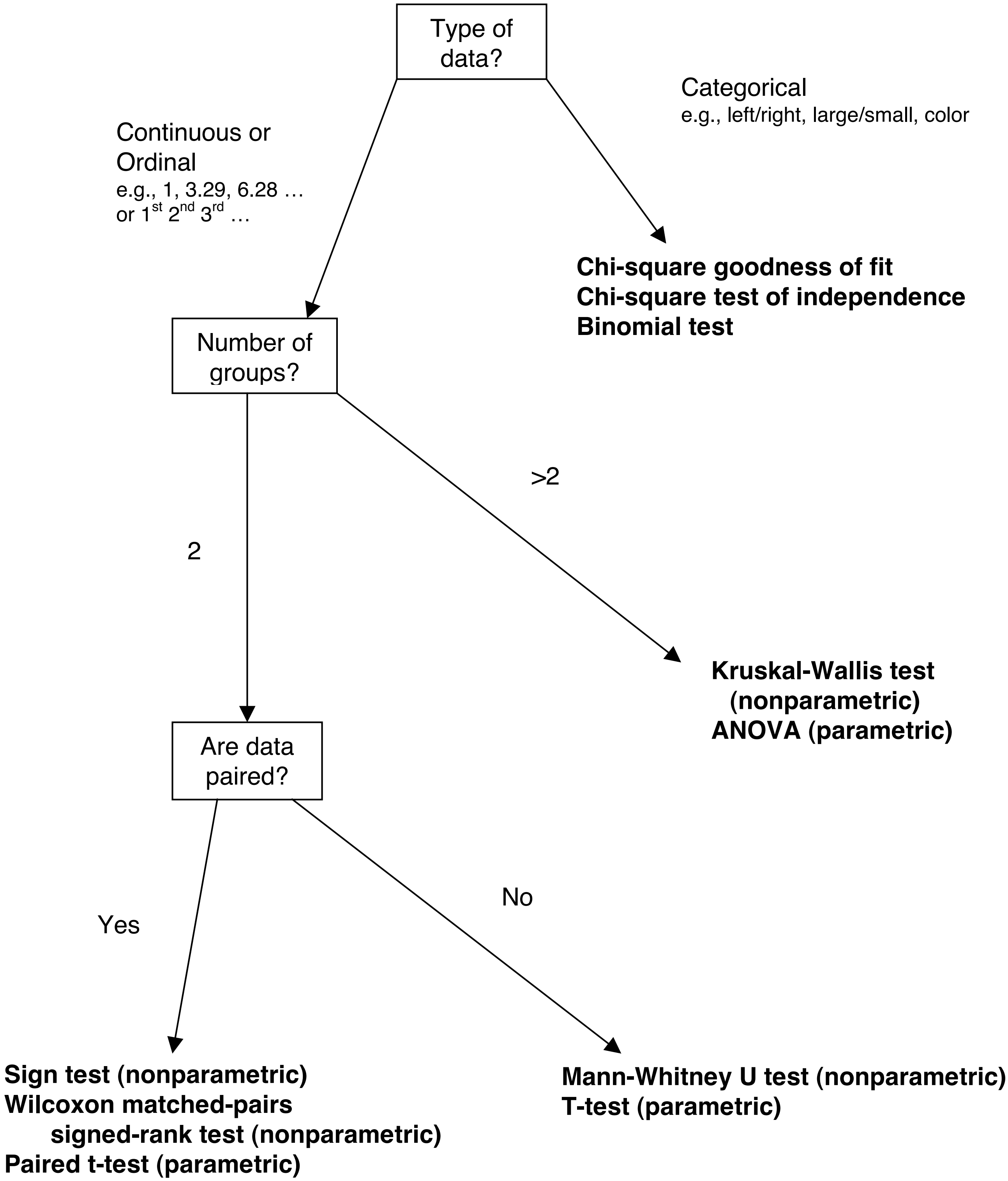

Figure 8.1. A flow chart to aid in deciding which statistical test is appropriate. Only common tests are included.

BEFORE CLASS: After examining the flow chart, look through the following tests.

1. Mann-Whitney U test

This test is used to determine the significance of differences between two sets of unpaired data. A ranking system is used.

Example: You are interested in whether the movement rate of the protozoan *Paramecium caudatum* is influenced by whether they are tested under dim or bright light. The null hypothesis is *P. caudatum* has the same rate of movement under both conditions. You measure movement rate by counting the number of squares in a counting chamber a *Paramecium* crosses every 10 seconds.

1. First, order each group from smallest to largest. Next, rank the data of the two groups combined. The lowest score (of *both* groups) gets a value of 1, the next highest (of *both* groups) a value of 2, etc. In the case of ties (for example, two values of 12), each value is ranked, the ranks are averaged, and the average rank is assigned to each of the tied scores: (11+12)/2 = 11.5. If you've done this properly, your last rank will equal *N*, the total number of samples.

Example: *P. caudatum* movement data (squares crossed per 10 sec.)

Dim Light	*Rank*	Bright Light	*Rank*
10	*7*	5	*1*
11	*9.5*	6	*2*
12	*11.5*	7	3
12	*11.5*	8	*4*
15	*13*	9	*5*
16	*14*	10	*7*
17	*15*	10	*7*
		11	*9.5*

2. Designate the sample size of the larger group as N_L and that of the smaller as N_S. In our example $N_L = 8$ and $N_S = 7$.

3. Sum the ranks (*T*) of each group.

$T_S = 7 + 9.5 + 11.5 + 11.5 + 13 + 14 + 15 = 81.5$

$T_L = 1 + 2 + 3 + 4 + 5 + 7 + 7 + 9.5 = 38.5$

4. Calculate the test statistics, U_S and U_L.

$$U_S = N_S N_L + \frac{N_S(N_S + 1)}{2} - T_S = 2.5$$

$$U_L = N_S N_L - U_S = 53.5$$

5. Choose the greater of the two values of *U*. This is the test statistic. Compare it to the critical value in Table 8.2. The test statistic must be higher than the critical value to be significant. In this example, the higher *U* is 53.5. Look in Table 8.2 under $N_L = 8$ and $N_S = 7$ at the 95% level ($P = 0.05$). The critical value for $P = 0.05$ is 43; since 53.5 > 43, we can reject the null hypothesis with 95% probability that rejection is correct. We conclude that *Paramecium* swim more slowly under bright light.

2. Kruskal-Wallis test

The Kruskal Wallis Test is similar to the Mann-Whitney U test, but here we have more than two groups. Work through the Mann-Whitney U example before attempting this one.

Example: You are interested in the antipredator behavior of garter snakes. You wonder how close you, as a simulated predator, can get before the snake crawls away. Because snakes are poikilotherms and can move more quickly when it is warmer, you suspect that this behavior is influenced by temperature. You compare three groups: snakes at 23°C, 25°C, and 27°C. The data are closest approach distance, in meters. The null hypothesis is that snakes tested under these three temperatures do not differ in how close an experimenter approaches before they flee.

1. First order and rank the data, as described for the Mann-Whitney *U* test. When there are tied scores, each score is given the mean of the ranks for which it is tied. Compute the sum of the ranks for each group, symbolized by *R*. R_1 is the sum of the ranks of group 1, etc.

Example: Flight distance of snakes (in meters)

23°C	*Rank*	25°C	*Rank*	27°C	*Rank*
0.5	*1*	0.75	*2*	3.5	*7*
1	*3*	3.25	*6*	5.5	*12*
1.25	*4*	4	*8*	6	*13*
3	*5*	4.75	*10*	8	*14*
4.25	*9*	5.25	*11*		
	$R_1 = 22$		$R_2 = 37$		$R_3 = 46$

2. Now compute the test statistic, H, using the following formula:

$$H = \frac{12}{N(N+1)} \sum \frac{R_i^2}{n_i} - 3(N+1)$$

In this formula, the $\sum$ is a summation sign, and indicates that you should sum up each R^2 value, from R_1 to R_3. Plugging in the appropriate numbers for *R*, *N* (the total number of observations), and n_i (the number of observations in each group):

$$H = \frac{12}{14(14+1)} \left[\frac{(22)^2}{5} + \frac{(37)^2}{5} + \frac{(46)^2}{4} \right] - 3(14+1) = 6.4$$

If you have a large number of ties, use the correction for ties. Compute *H* as above, then divide by

$$1 - \frac{\sum (t^3 - t)}{N^3 - N}$$

where *t* = the number of observations in a tied group of scores
N = the total number of all observations

3. Compare your test statistic with Table 8.3. The test statistic must be higher than the critical value to be significant. *H*, at 6.4, is greater than 5.6429, so you may reject the null hypothesis at $P < .05$. The three groups do differ.

3. Sign test

The sign test is used for two-groups when the data are paired. In this test, only the signs of the differences are used. Another nonparametric test, the Wilcoxon matched-pairs signed rank test, is more powerful because it uses both the signs and the magnitude of the differences. We will use the sign test as a general example of how paired data can be treated.

Example: You imagine that male mice might benefit from avoiding inbreeding, or mating with close relatives. Because mice depend on odor for a great deal of their information about the world, you decide to present males with soiled litter from the cages of females. You test each male twice: once with litter from his sister, and once with litter from a stranger. The females are sexually receptive, so the soiled litter should be rich in chemical cues. You present the litter in random order so that half the males get their sibling's litter first, and half get the stranger's litter first. Since the same males are tested twice, a Mann-Whitney U test is inappropriate. Null hypothesis: The number of sniffs per minute will be the same when males are exposed to the litter of their sisters vs. that of strangers.

Male ID Number	Number of Sniffs/Min with Sister's Litter	Number of Sniffs/Min with Stranger's Litter	Sign of the Difference
1	10	9	+
2	8	3	+
3	3	5	-
4	20	11	+
5	15	9	+
6	35	21	+
7	4	6	-
8	11	10	+
9	41	20	+
10	22	21	+
11	16	16	*0*
12	18	17	+
13	7	0	+
14	11	5	+

1. Subtract one data column from the other to determine the sign of the difference. (It doesn't matter which you subtract from which, just be consistent.)

2. Note the least frequent sign. In this case, the least frequent sign is negative, and there are two. The test statistic, x, therefore equals 2.

3. Determine N, the number of pairs which showed a difference. Here we disregard male #11, so $N = 13$.

4. Look at Table 8.4 for $N = 13$ along the left-hand side. Now find $x = 2$. The P value is 0.011 (the initial decimal places are omitted in the table to save space). You can therefore reject your null hypothesis at the 0.05 level.

4. Chi-square test of independence and chi-square goodness-of-fit test

Tests using the chi-square statistic are useful when you have nominal data (categories rather than numbers). For example, a category might be "large" vs. "small," "laid eggs" vs. "did not lay eggs," etc.

First we will look at the chi-square test of independence. This test helps us determine whether two variables are associated. If two variables are not associated (that is, they are independent), knowing the value of one variable will not help us determine the value of the other variable.

Example: When snails sense the presence of a nearby starfish, a predator, via chemicals in the water, they will climb. We can look at three groups of snails: the first group is the control group, with the snails exposed to plain sea water, the second group is exposed to water scented by a sea urchin (an herbivore), and the third group to sea water scented by a predatory starfish. The data collected for each snail is whether it climbed or not. These are categorical data: the snail could do one thing or the other. The categories are mutually exclusive (the snail could not "climb" *and* "not climb"). If the variables are independent, there will be no relationship between the type of water the snail is exposed to (the first variable) and how it responds (the second variable). Note: if instead of making categories of "climb" and "not climb," the experimenter had measured the distance each snail moved, the chi-square test would be inappropriate. (Which test should be used for those data?)

1. Make a table of *observed frequencies*, the data actually collected in the experiment.

Observed frequencies

	Source of Test Water			
Behavior	**Control**	**Sea urchin**	**Predator**	**Row totals**
Climb	12	14	24	50
Not climb	28	23	15	66
Column totals	40	37	39	Grand total = 116

Note: The grand total of the rows should equal the grand total of the columns.

2. Calculate and tabulate the *expected frequency* for each category (for the number of snails observed, the frequency expected in each category if there is no relationship between the variables):

$$\frac{\text{column total x row total}}{\text{grand total}}$$

Expected frequencies

	Source of Test Water			
Behavior	**Control**	**Sea urchin**	**Predator**	**Row totals**
Climb	17.2	16	16.8	50
Not climb	22.8	21	22.2	66
Column totals	40	37	39	Grand total = 116

3. Calculate the value of chi-square (x^2):

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

where:
O = the observed frequency in each cell
E = the expected frequency in each cell

$$\chi^2 = \frac{(12 - 17.2)^2}{17.2} + \frac{(28 - 22.8)^2}{22.8} + \frac{(14 - 16)^2}{16} + \frac{(23 - 21)^2}{21} + \frac{(24 - 16.8)^2}{16.8} + \frac{(15 - 22.2)^2}{22.2}$$

$x^2 = 8.62$

4. Examine the table of critical values for this test (see Table 8.5). The *df* column corresponds to the degrees of freedom for this test. Degrees of freedom is a number that results from the way the data are organized, and refers to whether the observations are free to vary. For example, if all of 50 observations must fall into two categories, as soon as we know that one category holds 41 data points, then the other category holds nine. For every statistical test, there are established methods for determining degrees of freedom. For the chi-square test, the formula is:

df = (# rows – 1) (# columns - 1) = (2–1) (3–1) = 2

We compare the test statistic to the critical value: if it is bigger, we reject the null hypothesis. The calculated x^2 is 8.62, which is greater than 5.99. The three groups of snails moved differently.

A second type of chi-square test is called the chi-square goodness-of-fit test. In this case, the experimenter tests to see how the data match expected values that were determined before the test was run. For example, in Mendelian genetics, we can predict the outcome of different crosses; the ratio of the different types of offspring is known in advance. In this case, we compare the observed values from the experiment with the expected values, generated by theory. The calculations are performed in exactly the same way as for the chi-square test of independence.

5. The binomial test

This test is useful for categorical data where we have only two categories, and when we are interested in testing whether the data are equally likely to fall into either category.

Example: You've been using a coin to randomly assign treatments to your experimental animals, but you are beginning to suspect that the coin is not fair, and you decide you'd better test this. The null hypothesis is: the coin is equally likely to come up tails as heads.

1. Flip the coin 11 times. Nine times it comes up heads, and twice it comes up tails.

2. Using Table 8.4, locate the value for N (in this case, 11) along the left side, and the smallest numerical score (x; in this case, 2) along the top. The probability associated with this distribution is 0.033 (i.e., $P = 0.033$). Because $P < 0.05$, we can reject our null hypothesis: the coin is not fair.

IN CLASS

After you have reviewed the flow chart and glanced through the worked examples, attempt the following problems. In each, an experiment is described. Determine which statistical test is most appropriate, and answer all questions posed. Refer back to the worked examples to help you understand how to conduct each test.

1. Elephants make low-frequency sounds, inaudible to humans. Apparently these sounds are used in long-distance communication between individuals. You are interested in the response of bull and female elephants to the sound of a female who is ready to mate. You mount a giant speaker on top of your van and drive around the plains looking for elephants. When you find one, you stop 15 m away, play the sound and watch the elephant's response. You discover:

9 bull elephants approach the van
2 bull elephants do not approach the van
3 female elephants approach the van
11 female elephants do not approach the van

Your experiment ends prematurely when one of the bull elephants, apparently enraged by the absence of a female, tips the van over and damages the speaker. You hope that you have enough data to make a claim about males and females.

a. What is the null hypothesis?
b. What statistical test should you use?
c. Calculate your test statistic. Is your result statistically significant?
d. What conclusion can you draw from this experiment?

2. Male butterflies sometimes court females of other species with similar wing patterns. You are interested in how long males persist in courting the wrong female. You decide to test each male with a dead female, to control for the effect of the female's behavior. You use three types of test females: one from the same species as the males, one from a different species with a similar wing pattern, and one from a different species with a different wing pattern. Each pair is placed in a cage, and you measure courtship time in seconds.

Female of same species: 23, 20, 17, 25, 28
Female of different species, similar pattern: 18, 27, 24, 21
Female of different species, different pattern: 22, 21, 23, 20

a. Calculate the mean, variance, and standard deviation for each group.
b. Qualitatively compare the means and standard deviations for each group. (Do they look very different? Very similar?)
c. Which statistical test would you use to look for differences?
d. Perform the test. What is your test statistic? Can you reject your null hypothesis?
e. Give a biological reason why your test may have come out the way it did.

3. Honeybees returning from foraging convey information to bees in the hive about the location of food resources. One way they do this is through a waggle dance that other bees watch. Another way they convey information is by regurgitating some of the food they have collected to other bees, a process known as trophyllaxis. You are interested in the speed at which bees find a resource another bee "tells" them about. You decide to compare bees that have only observed a dance with bees that have observed a dance *and* accepted regurgitated food. You mark a lot of bees with bee tags (little numbered discs that you glue to the back of the thorax). This enables you to watch the same individual repeatedly. One day you choose a lot of bees that have seen a waggle dance but not accepted food. You measure (in seconds) how long it takes for them to find the resource. A week later you go back to the hive, and find the same individuals. This time you watch until they see a dance *and* accept food, and again measure how long it takes them to reach the resource.

Here are your data. The numbers are seconds needed for the bee to reach the resource.

Bee #	Watch Only	Watch and Accept Food
1	87	80
2	53	48
3	57	57
4	89	88
5	48	38
6	109	160
7	109	100
8	48	78
9	29	26
10	45	41
11	67	53
12	120	98
13	55	55
14	89	78

a. What sort of data are these? Which test should you choose?
b. What is the test statistic? The table statistic?
c. You decide that a bee that has both watched and gotten food from another bee finds the resource faster than one that has just watched. What other factor that is a result of your experimental protocol might also explain your results?

Table 8.1 Formulas for descriptive statistics

Y_i is an observation, or data point. The first observation is Y_1, the second is Y_2, etc.

N is the sample size, or the number of observations.

Mean:

$$\bar{Y} = \frac{\sum Y_i}{N}$$

Variance:

$$s^2 = \frac{\sum \left(Y_i - \bar{Y}\right)^2}{N - 1}$$

Standard deviation:

$$s = \sqrt{s^2}$$

Standard error:

$$\frac{s}{\sqrt{N}}$$

Median: Rank the values from lowest to highest and take the center-most value.

Mode: The most common value.

Table 8.2 Critical values of U, the Mann-Whitney statistic for P = 0.05 and 0.01.
(Modified from Table 29, F.J. Rohlf and R.R. Sokal. 1981. *Statistical Tables*, 2nd edition. W.H. Freeman and Company.)

N_L	N_S	$P = 0.05$	$P = 0.01$
3	2		
	3	9	
4	2		
	3	12	
	4	15	
5	2	10	
	3	14	
	4	18	20
	5	21	24
6	2	12	
	3	16	
	4	21	23
	5	25	28
	6	29	33
7	2	14	
	3	19	21
	4	24	27
	5	29	32
	6	34	38
	7	38	43
8	2	15	
	3	21	24
	4	27	30
	5	32	36
	6	38	42
	7	43	49
	8	49	55
9	2	17	
	3	23	26
	4	30	33
	5	36	40
	6	42	47
	7	48	54
	8	54	61
	9	60	67
10	2	19	
	3	26	29
	4	33	37
	5	39	44
	6	46	52
	7	53	59
	8	60	67
	9	66	74
	10	73	81

N_L	N_S	**0.05**	**0.01**
11	2	21	
	3	28	32
	4	36	40
	5	43	48
	6	50	57
	7	58	65
	8	65	73
	9	72	81
	10	79	88
	11	87	96
12	2	22	
	3	31	34
	4	39	42
	5	47	52
	6	55	61
	7	63	70
	8	70	79
	9	78	87
	10	86	96
	11	94	104
	12	102	113
13	2	24	26
	3	33	37
	4	42	47
	5	50	56
	6	59	66
	7	67	75
	8	76	84
	9	84	94
	10	93	103
	11	101	112
	12	109	121
	13	118	130
14	2	25	28
	3	35	40
	4	45	50
	5	54	60
	6	63	71
	7	72	81
	8	81	90
	9	90	100
	10	99	110
	11	108	120
	12	117	130
	13	126	139
	14	135	149

Table 8.3 Probabilities associated with values as large as observed values of H in Kruskal-Wallis tests.
(Modified from Table O in S. Siegel. 1956. *Nonparametric Statistics for the Behavioral Sciences*. McGraw-Hill, New York.)

Sample Sizes				
N_1	**N_2**	**N_3**	***H***	***P***
2	1	1	2.7000	.500
2	2	1	3.6000	.200
2	2	2	4.5714	.067
			3.7143	.200
3	1	1	3.2000	.300
3	2	1	4.2857	.100
			3.8571	.133
3	2	2	5.3572	.029
			4.7143	.048
			4.5000	.067
			4.4643	.105
3	3	1	5.1429	.043
			4.5714	.100
			4.0000	.129
3	3	2	6.2500	.011
			5.3611	.032
			5.1389	.061
			4.5556	.100
			4.2500	.121
3	3	3	7.2000	.004
			6.4889	.011
			5.6889	.029
			5.6000	.050
			5.0667	.086
			4.6222	.100
4	1	1	3.5714	.200
4	2	1	4.8214	.057
			4.5000	.076
			4.0179	.114
4	2	2	6.0000	.014
			5.3333	.033
			5.1250	.052
			4.4583	.100
			4.1667	.105

Sample Sizes				
N_1	**N_2**	**N_3**	**H**	**P**
4	3	1	5.8333	.021
			5.2083	.050
			5.0000	.057
			4.0556	.093
			3.8889	.129
4	3	2	6.4444	.008
			6.3000	.011
			5.4444	.046
			5.4000	.051
			4.5111	.098
			4.4444	.102
4	3	3	6.7455	.010
			6.7091	.013
			5.7909	.046
			5.7273	.050
			4.7091	.092
			4.7000	.101
4	4	1	6.6667	.010
			6.1667	.022
			4.9667	.048
			4.8667	.054
			4.0667	.102
4	4	2	7.0364	.006
			6.8727	.011
			5.4545	.046
			5.2364	.052
			4.5545	.098
			4.4455	.103
4	4	3	7.1439	.010
			7.1364	.011
			5.5985	.049
			5.5758	.051
			4.5455	.099
			4.4773	.102
4	4	4	7.6539	.008
			7.5385	.011
			5.6923	.049
			5.6538	.054
			4.6539	.097
			4.5001	.104
5	1	1	3.8571	.143

Sample Sizes				
N_1	**N_2**	**N_3**	**H**	**P**
5	2	1	5.2500	.036
			5.0000	.048
			4.4500	.071
			4.2000	.095
			4.0500	.119
5	2	2	6.5333	.008
			6.1333	.013
			5.1600	.034
			5.0400	.056
			4.3733	.090
			4.2933	.122
5	3	1	6.4000	.012
			4.9600	.048
			4.8711	.052
			4.0178	.095
			3.8400	.123
5	3	2	6.9091	.009
			6.8218	.010
			5.2509	.049
			5.1055	.052
			4.6509	.091
			4.4945	.101
5	3	3	7.0788	.009
			6.9818	.011
			5.6485	.049
			5.5152	.051
			4.5333	.097
			4.4121	.109
5	4	1	6.9545	.008
			6.8400	.011
			4.9855	.044
			4.8600	.056
			3.9873	.098
			3.9600	.102
5	4	2	7.2045	.009
			7.1182	.010
			5.2727	.049
			5.2682	.050
			4.5409	.098
			4.5182	.101

Sample Sizes				
N_1	**N_2**	**N_3**	***H***	***P***
5	4	3	7.4449	.010
			7.3949	.011
			5.6564	.049
			5.6308	.050
			4.5487	.099
			4.5231	.103
5	4	4	7.7604	.009
			7.7440	.011
			5.6571	.049
			5.6176	.050
			4.6187	.100
			4.5527	.102
5	5	1	7.3091	.009
			6.8364	.011
			5.1273	.046
			4.9091	.053
			4.1091	.086
			4.0364	.105
5	5	2	7.3385	.010
			7.2692	.010
			5.3385	.047
			5.2462	.051
			4.6231	.097
			4.5077	.100
5	5	3	7.5780	.010
			7.5429	.010
			5.7055	.046
			5.6264	.051
			4.5451	.100
			4.5363	.102
5	5	4	7.8229	.010
			7.7914	.010
			5.6657	.049
			5.6429	.050
			4.5229	.099
			4.5200	.101
5	5	5	8.0000	.009
			7.9800	.101
			5.7800	.049
			5.6600	.051
			4.5600	.100
			4.5000	.102

Table 8.4 Table of probabilities associated with values as small as observed values of *x*, for use in sign test and binomial test. Values for total sample size are in the left-hand column, and values for *x* are across the top. Decimal places are omitted in order to save space.
(Table D in S. Siegel. 1956. *Nonparametric Statistics for the Behavioral Sciences.* McGraw-Hill, New York.)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
5	031	188	500	812	969	*										
6	016	109	344	656	891	984	*									
7	008	062	227	500	773	938	992	*								
8	004	035	145	363	637	855	965	996	*							
9	002	020	090	254	500	746	910	980	998	*						
10	001	011	055	172	377	623	828	945	989	999	*					
11		006	033	113	274	500	726	887	967	994	*	*				
12		003	019	073	194	387	613	806	927	981	997	*	*			
13		002	011	046	133	291	500	709	867	954	989	998	*	*		
14		001	006	029	090	212	395	605	788	910	971	994	999	*	*	
15			004	018	059	151	304	500	696	849	941	982	996	*	*	*
16			002	011	038	105	227	402	598	773	895	962	989	998	*	*
17			001	006	025	072	166	315	500	685	834	928	975	994	999	*
18			001	004	015	048	119	240	407	593	760	881	952	985	996	999
19				002	010	032	084	180	324	500	676	820	916	968	990	998
20				001	006	021	058	132	252	412	588	748	868	942	979	994
21				001	004	013	039	095	192	332	500	668	808	905	961	987
22					002	008	026	067	143	262	416	584	738	857	933	974
23					001	005	017	047	105	202	339	500	661	789	895	953
24					001	003	011	032	076	154	271	419	581	729	846	924
25						002	007	022	054	115	212	345	500	655	788	885

*1 or approximately 1.

Table 8.5 Table of probabilities for the chi-square distribution.
(Modified from Table 14, Rohlf, F.J. and R.R. Sokal. 1981. *Statistical Tables,* 2nd edition. W. H. Freeman and Company.)

Degrees of freedom	***P* = 0.05**	***P* = 0.01**
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