ISE 468 ETM 568 Non-parametric in-class activity: Solutions

Problem 1

Use the sign test to determine if the different instruments yield different results.

We have paired readings for 14 days using instrument A and instrument B.

For the sign test, we do not need actual difference scores, we simply need the

sign of the difference when we are testing the median equals 0 vs. not equal 0.

The hypothesis is non-directional (≠).

I recorded the sign of the ordered difference of Instrument A minus Instrument B.

sulfur readings

1

1

1

1

1

-1

1

1

1

-1

1

1

1

1

MTB > STest 0 'sulfur readings';

SUBC> Alternative 0.

**Sign Test for Median: sulfur readings**

Sign test of median = 0.00000 versus ≠ 0.00000

N Below Equal Above P Median

sulfur readings 14 2 0 12 0.0129 1.000

H0 The sulfur readings for instrument A and instrument B are the same.

H1 The sulfur readings for instrument A and instrument B are not the same.

We reject H0.

Based on a p-value of 0.0129, we conclude that the sulfur readings for the two instruments are significantly different.

Problem 2

For Problem 2 we are given three groups of data and told to conduct a Kruskal-Wallis Test to test the hypothesis that the operating times for the three calculators are equal.

In Minitab, we determine that the responses must be in a single column and the factor levels

in a different column.

TimeABC CalculatorABC

4.9 CalcA

4.6 CalcA

6.1 CalcA

5.2 CalcA

4.3 CalcA

5.5 CalcB

5.8 CalcB

5.4 CalcB

5.5 CalcB

4.8 CalcB

6.2 CalcB

5.2 CalcB

6.4 CalcC

6.5 CalcC

6.8 CalcC

6.3 CalcC

MTB > Kruskal-Wallis 'TimeABC' 'CalculatorABC'.

**Kruskal-Wallis Test: TimeABC versus CalculatorABC**

Kruskal-Wallis Test on TimeABC

CalculatorABC N Median Ave Rank Z

CalcA 5 4.900 4.7 -2.15

CalcB 7 5.500 7.8 -0.53

CalcC 4 6.450 14.5 2.91

Overall 16 8.5

H = 9.70 DF = 2 P = 0.008

H = 9.72 DF = 2 P = 0.008 (adjusted for ties)

\* NOTE \* One or more small samples

H0 The median times for the three calculators are equal.

H1 The median times for the three calculators are not all equal.

We reject H0.

Based on a p-value of 0.008, we conclude that the median operating times for the three calculators are not all equal.

It is not correct to say the median times are all not equal, or that the median times are different.

Problem 3

Is the tar content of brandb lower than branda? Use rank-sum test.

We have two samples that are not paired. They are independent or non-related samples.

This is a directional test. Is “brandb < branda” ?

Minitab Help tells us that the Mann-Whitney is a rank-sum test.

We do not need to place responses in one column and factors in another.

branda brandb

1 8

12 10

9 7

13

11

14

I will enter BrandA as the first response so I will choose > as the alternative hypothesis.

MTB > Mann-Whitney 95.0 'branda' 'brandb';

SUBC> Alternative 1.

**Mann-Whitney Test and CI: branda, brandb**

N Median

branda 6 11.500

brandb 3 8.000

Point estimate for η1 - η2 is 3.000

97.2 Percent CI for η1 - η2 is (-9.000,6.998)

W = 35.0

Test of η1 = η2 vs η1 > η2 is significant at 0.1226

Based on a p-value of 0.1225, we conclude that there is no significant difference in the median tar content of the two brands.

Note that the Minitab output for the Mann-Whitney Test does not use the term p-value.

Instead, it uses the phrase “is significant at”.

Problem 4

For Problem 4 we are given before and after data on 5 individuals and told to use signed-rank test in order to test the hypothesis that weight increases if you stop smoking. This is a directional test.

\*

MTB > WTest 0 'kg after-before';

SUBC> Alternative 1.

**Wilcoxon Signed Rank Test: kg after-before**

Test of median = 0.000000 versus median > 0.000000

N for Wilcoxon Estimated

N Test Statistic P Median

kg after-before 5 5 11.5 0.173 1.500

\*

MTB > WTest 0 'kilograms before-after';

SUBC> Alternative -1.

**Wilcoxon Signed Rank Test: kilograms before-after**

Test of median = 0.000000 versus median < 0.000000

N for Wilcoxon Estimated

N Test Statistic P Median

kilograms before-after 5 5 3.5 0.173 -1.500

\*

MTB > WTest 0 'kilograms before-after';

SUBC> Alternative 0.

**Wilcoxon Signed Rank Test: kilograms before-after**

Test of median = 0.000000 versus median ≠ 0.000000

N for Wilcoxon Estimated

N Test Statistic P Median

kilograms before-after 5 5 3.5 0.345 -1.500

**Paired T-Test and CI: kgafter, kgbefore**

Paired T for kgafter - kgbefore

N Mean StDev SE Mean

kgafter 5 70.00 9.41 4.21

kgbefore 5 68.40 10.64 4.76

Difference 5 1.60 3.05 1.36

95% lower bound for mean difference: -1.31

T-Test of mean difference = 0 (vs > 0): T-Value = 1.17 P-Value = 0.153

Problem 5

For Problem 5 we are given data on the number of prescriptions filled by two different pharmacies on 20 specific days. Does pharmacy A fill more prescriptions than pharmacy B?

This is paired data and directional. We are asked to use the signed-rank test.

pharmacy a-b

2

6

3

5

8

-3

8

1

6

-3

4

6

6

2

-4

3

7

1

-2

4

MTB > WTest 0 'pharmacy a-b';

SUBC> Alternative 1.

**Wilcoxon Signed Rank Test: pharmacy a-b**

Test of median = 0.000000 versus median > 0.000000

N for Wilcoxon Estimated

N Test Statistic P Median

pharmacy a-b 20 20 180.0 0.003 3.250

Based on a p-value of 0.003 we conclude the median number of prescriptions for pharmacy a

is significantly larger than pharmacy b.

MTB > STest 0 'pharmacy a-b';

SUBC> Alternative 1.

**Sign Test for Median: pharmacy a-b**

Sign test of median = 0.00000 versus > 0.00000

N Below Equal Above P Median

pharmacy a-b 20 4 0 16 0.0059 3.500

Based on a p-value of 0.0059 we conclude the median number of prescriptions for pharmacy a

is significantly larger than pharmacy b.

Problem 6

Use the sign test to determine if median systolic blood pressure increases by less than 8 points after jogging. We have paired readings for 16 joggers. The hypothesis is directional.

For the sign test, we do not need actual difference scores, we simply need the

sign of the difference. However, in this case we are using the difference scores to test the hypothesis that the median is 8 vs. <8. I recorded the actual data and calculated the difference scores. Note that the systolic blood pressure was higher for each jogger.

jogafter-before

6

9

3

5

8

9

4

10

8

2

6

3

1

6

8

11

**Sign Test for Median: jogafter-before**

Sign test of median = 8.000 versus < 8.000

N Below Equal Above P Median

jogafter-before 16 9 3 4 0.1334 6.000

Based on a p-value of 0.1334, we conclude the median change in systolic blood pressure is not significantly less than 8.

Problem 7

Consider the observed frequencies (count data) for changing a law (For, Against, Undecided) based on political affiliation (Democrat, Republican, Independent).

This is a chi-square test of association or independence.

Minitab uses association.

Minitab Help : Perform a chi-square test of association between variables.

The null hypothesis states that no association exists.

dem rep ind

for 82 70 62

against 93 62 67

undec 25 18 21

I choose Tables/Chi-Square Test for Association and enter the columns for the count data and the rows for the categories (optional).

I choose to list contribution to chi-square as well.

**Chi-Square Test for Association: C23, Worksheet columns**

Rows: C23 Columns: Worksheet columns

dem rep ind All

for 82 70 62 214

85.60 64.20 64.20

0.15140 0.52399 0.07539

against 93 62 67 222

88.80 66.60 66.60

0.19865 0.31772 0.00240

undec 25 18 21 64

25.60 19.20 19.20

0.01406 0.07500 0.16875

All 200 150 150 500

Cell Contents: Count

Expected count

Contribution to Chi-square

Pearson Chi-Square = 1.527, DF = 4, P-Value = 0.822

Likelihood Ratio Chi-Square = 1.517, DF = 4, P-Value = 0.824

The large p-value indicates the data support the null hypothesis.

Based on a p-value of 0.822, we conclude that there is no association between political affiliation and position on changing the law.