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# Statistical Methods 9. Nonparametric Testing

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National HE STEM Programme



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# Overview of workshop

- What are nonparametric methods?
- When should you use them?
- Overview of nonparametric methods
- Comparing two groups:
  - Mann-Whitney U test
- Cross-tabulating two variables:
  - Chi-squared test of association
  - Fisher’s exact test



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# Parametric v. nonparametric methods

- Theoretical statistical distributions are constructed using parameters:
  - These parameters determine the location and shape of the frequency distribution
  - For example, the mean and standard deviation of the normal distribution – see Workshop 6
- Methods that assume observations come from a certain distribution are called **parametric methods**
- Methods that make no distributional assumptions about observations are called **nonparametric methods**

# When should non-parametric tests be used?

- When scale-based data does not satisfy the assumptions of the appropriate test or the conditions of its robust use
- For testing hypotheses with categorical (nominal/ordinal) data
- The advantage of nonparametric tests is that we do not have to test any assumptions or robustness conditions


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# Limitations

- Nonparametric methods are **less powerful** than parametric methods
- For example, for normally distributed data, a two sample t-test will detect a smaller real difference than the corresponding non-parametric test
- Application of nonparametric methods is difficult or impossible for complex data structures
- Nonparametric methods mainly involve hypothesis testing: less descriptive statistics can be calculated, for example, only maximum, minimum, median and quartiles for scale or ordinal data

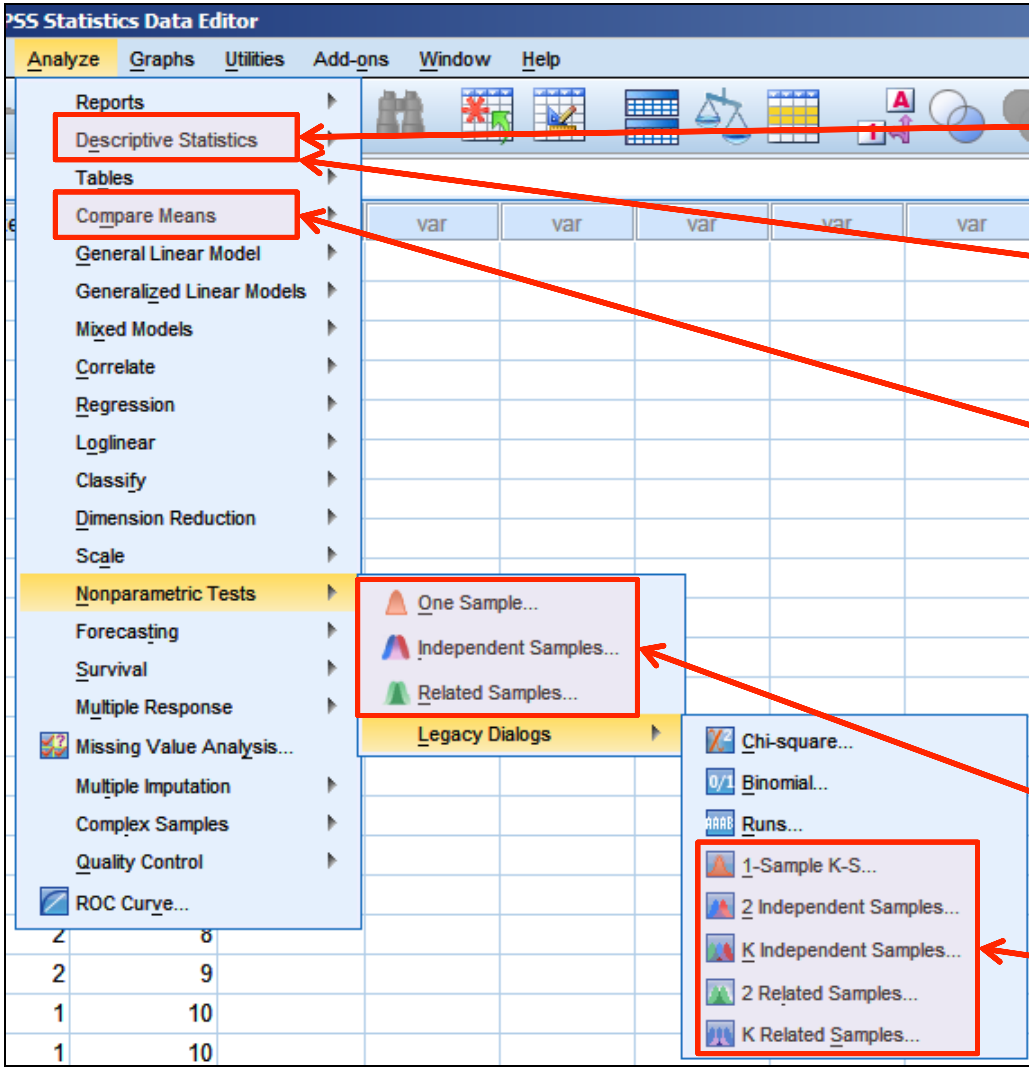
# Ranks

- Many nonparametric methods replace scale/ ordinal observations with ranks:

| Observation | 170 | 112 | 29 | 125 | 224 | 78 |
|---|---|---|---|---|---|---|
| Rank | 5 | 3 | 1 | 4 | 6 | 2 |

- Nonparametric test statistics are then based on ordering the data and working with the ranks
- SPSS takes care of all the details

# Nonparametric statistics in SPSS




Chi-squared and Spearman's correlation under Crosstabs

Normality tests under Explore

Alternative K Independent samples tests under One-Way ANOVA

Two choices with other nonparametric tests – new or legacy:

- New algorithms are better and output is more 'helpful'
- Legacy versions are less strict with data types



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# Nonparametric tests in SPSS

- **One sample:** Tests whether a sample of data follows a particular distribution
- **2 independent samples:** Compares two groups of cases (like an independent samples t-test – see Workshop 8)
- **K independent samples:** Compares two or more groups of cases (like a one-way ANOVA – see Workshop 10)
- **2 related samples:** Compares two paired groups of cases (like a paired-samples t-test – see Workshop 8)
- **K related samples:** Compares two or more related groups of cases (like repeated measures ANOVA)
- **2 ordinal/scale variables**: Spearman correlation and chi-squared test for association, and Fisher's exact test

# Example 1: Female stroke patients

- 100 female stroke patients were randomly assigned to one of two groups:
  - A standard physical therapy group (*Control*)
  - A group with the standard therapy plus emotional therapy (*Treatment*)
- Three months later the patients were evaluated on their ability to perform common Activities of Daily Life (ADL):

| Code | Travel | Cooking | Housekeeping |
|---|---|---|---|
| 0 | Same as before illness | Plans and prepares meals | As before |
| 1 | Gets out if someone else drives | Some cooking but less than before | Does at least half usual |
| 2 | Gets out in wheelchair | Gets food out if prepared by others | Occasional dusting of small jobs |
| 3 | Home or hospital bound | Does nothing for meals | No longer keeps house |
| 4 | Bed-ridden | Never did any | Never did any |

# Research question

- Does the additional therapy have an affect on any of these three measures activities for daily life?
- Null hypotheses:
  - The distribution of values for each measure does not depend on the group
- Alternative hypotheses:
  - The distribution of values for each measure does depend on the group



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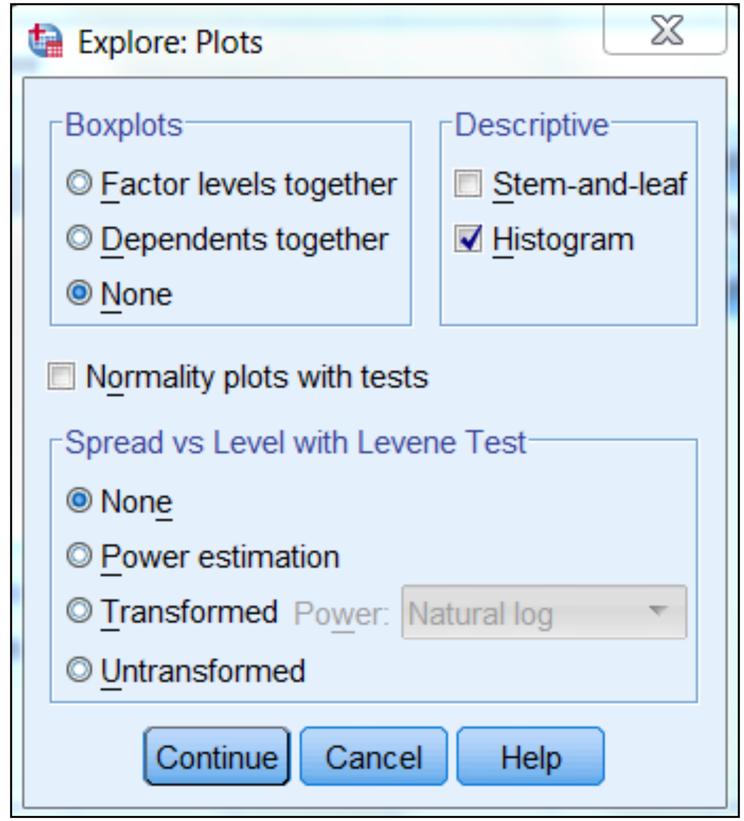
# Step 1: descriptive statistics

- Open the file ADL.sav associated with this presentation
- Select Analyze – Descriptive Statistics – Explore…
- Select the three measures in the Dependent List and *Group* as the Factor List
- Select Plots… and choose None under boxplots and Histogram under descriptive



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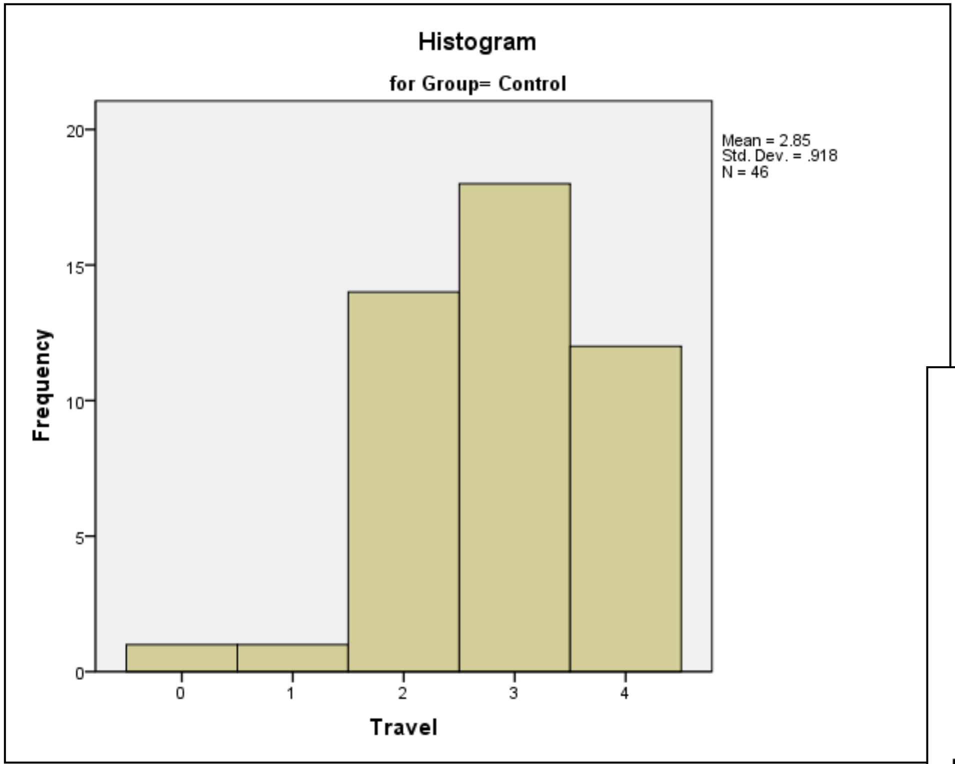
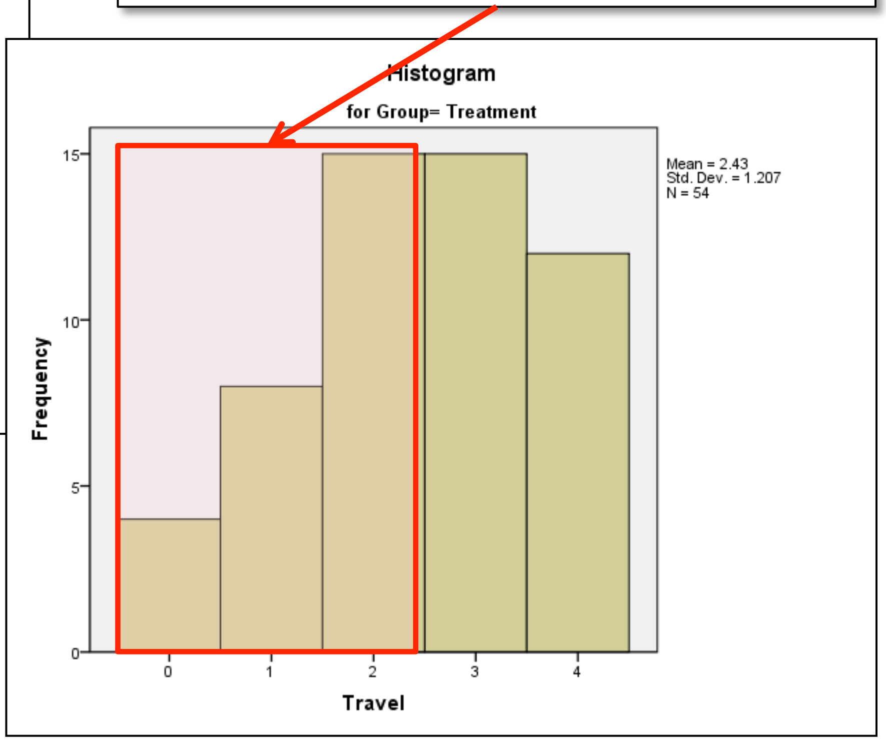
# Distribution of *Travel* by *Group*




Percentage frequency of Treatment group is relatively higher for lower values of Travel




Thus the Treatment appears to be having a positive effect



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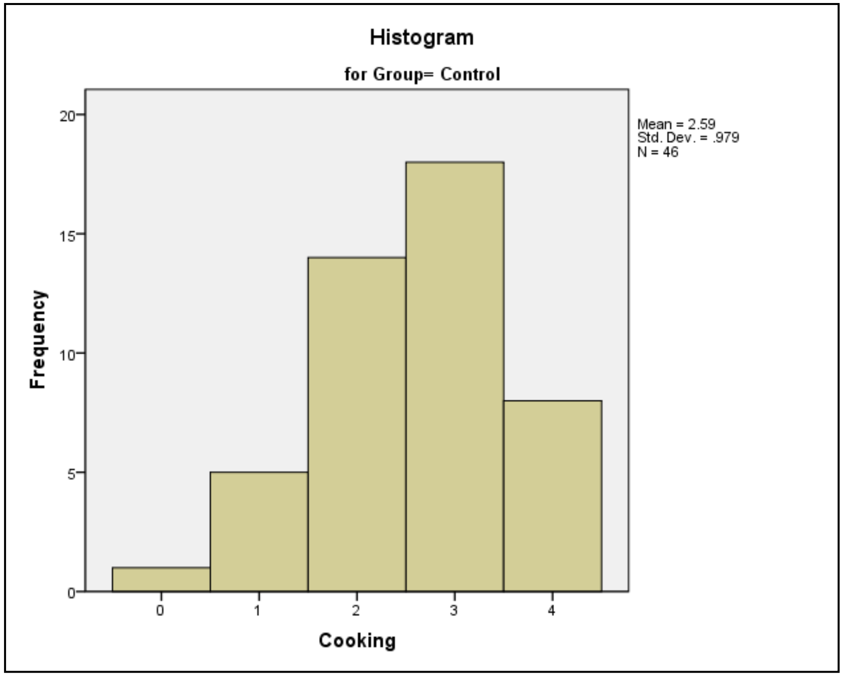
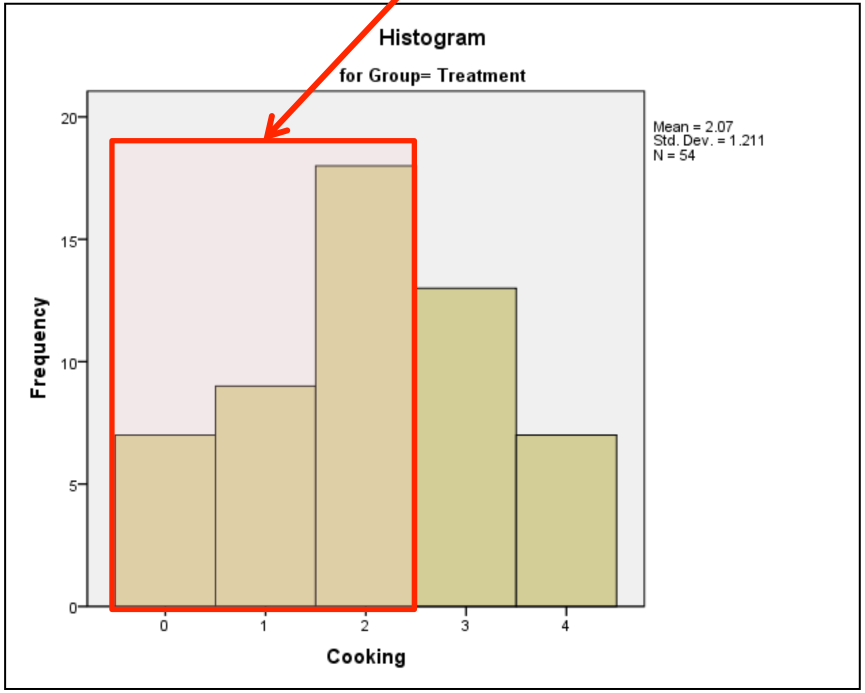
# Distribution of *Cooking* by *Group*

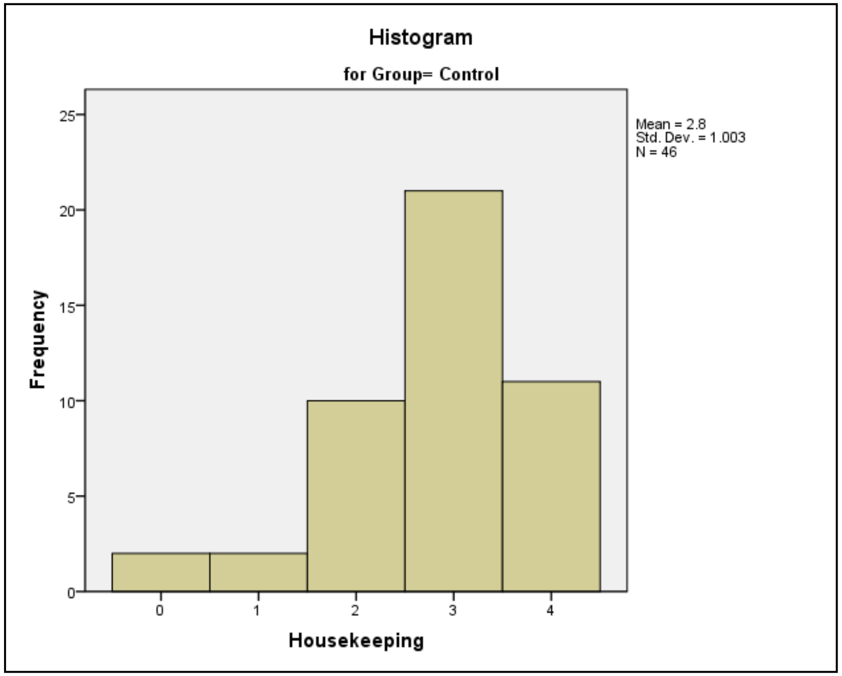



Difference in percentage frequencies bigger than for Travel




Thus the Treatment appears to be having a bigger positive effect

# Distribution of *Housekeeping* by *Group*




Difference in percentage frequencies even bigger than for Cooking


Thus the Treatment appears to be having an even bigger positive effect





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# Step 2: which test?

- The data is ordinal so we need to use a nonparametric test
- There are 2 independent groups
- The descriptive statistics suggest we should compare higher/lower ordinal values for the groups rather than general differences in shape
- The appropriate test is therefore the Mann-Whitney U test
- **Note**: If there had been other kinds of shape difference we should have used the chi-squared test
- **Note**: The category 4 data should be removed from each variable before it is tested because it corresponds to ‘not applicable’





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# Mann-Whitney U test

- A **non-parametric** test of two independent samples of ordinal or scale-based data
- Generally needs at least 5 data categories for the ordinal variable (here we only have 4 when the last case is removed, which is a bit of a problem)
- Alternative to an independent samples t-test for scale-based data if the test assumptions or robustness assumptions are not met
- Samples can be different sizes
- **Null hypothesis**: Values of *Travel* for the *Control* group are equally likely to be higher or lower than the values of *Travel* for the *Treatment* group



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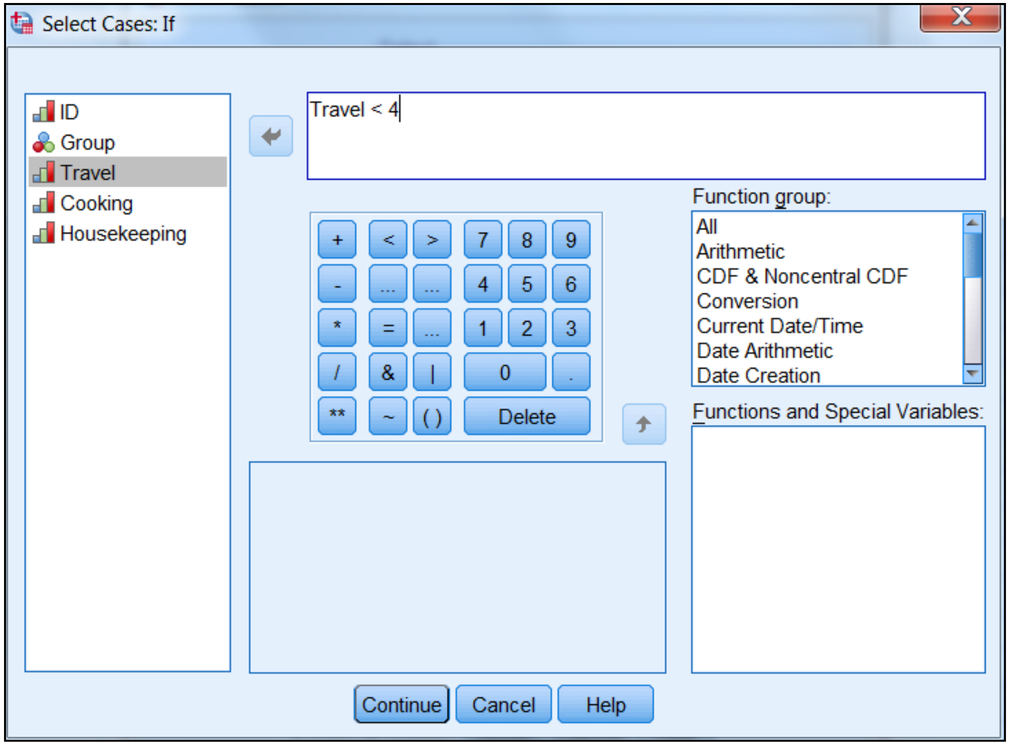
# Step 3: remove the cases with *Travel* = 4

- ❑ Select Data – Select Cases
- ❑ Click on the If condition is satisfied radio button
- ❑ Select the If… button
- ❑ Select *Travel* then click on ‘<‘ and 4
- ❑ Select Continue etc.



# Step 4: run the test

- Select Analyze – Nonparametric Tests – Legacy Dialogs – 2 Independent Samples…
- **Note**: we cannot use the new version of this test with an ordinal data type for the test variable
- Select Travel for the Test Variable List and Group for the Grouping Variable
- Click on Define Groups and select 0 for Group 1 and 1 for Group 2
- The Mann-Whitney U test is selected by default



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# Step 5: interpret the output

- Significance value of test is 0.032
- We reject the null hypothesis with 95% confidence, i.e. there is evidence that treatment is having an effect. The effect is also positive (negative Z value).
- Repeat the same analysis for *Cooking* and *Housekeeping* (first select the appropriate cases)
- Same result obtained for *Cooking*, p-value is slightly smaller (so evidence is slightly stronger)
- Even stronger result obtained for *Housekeeping* – null hypothesis rejected with 99% confidence – strong evidence that treatment is having an effect

**Test Statistics**[a]

| | Travel |
|---|---|
| Mann-Whitney U | 524.000 |
| Wilcoxon W | 1427.000 |
| Z | -2.139 |
| Asymp. Sig. (2-tailed) | .032 |

a. Grouping Variable: Group

**Test Statistics**[a]

| | Cooking |
|---|---|
| Mann-Whitney U | 646.000 |
| Wilcoxon W | 1774.000 |
| Z | -2.310 |
| Asymp. Sig. (2-tailed) | .021 |

a. Grouping Variable: Group

**Test Statistics**[a]

| | Housekeeping |
|---|---|
| Mann-Whitney U | 553.500 |
| Wilcoxon W | 1681.500 |
| Z | -2.700 |
| Asymp. Sig. (2-tailed) | .007 |

a. Grouping Variable: Group

# Example 2 : Smartphone purchasing survey

**92 people were asked:**

**Q1**: What is your gender?

- Male
- Female

**Q2**: What is you age?

*This is recorded in the following categories:*

*17-24, 25-29, 30-39 and 40+*

**Q3**: On a scale of 0 to 10 how important do you consider brand when purchasing a smartphone?

(where 0 = extremely unimportant and 10 = extremely important)

# Research questions

1. Is the importance of brand when purchasing a smartphone gender related?
2. Is the importance of brand when purchasing a smartphone age related?

**Null hypotheses:**

1. Brand importance is not gender related
2. Brand importance is not age related



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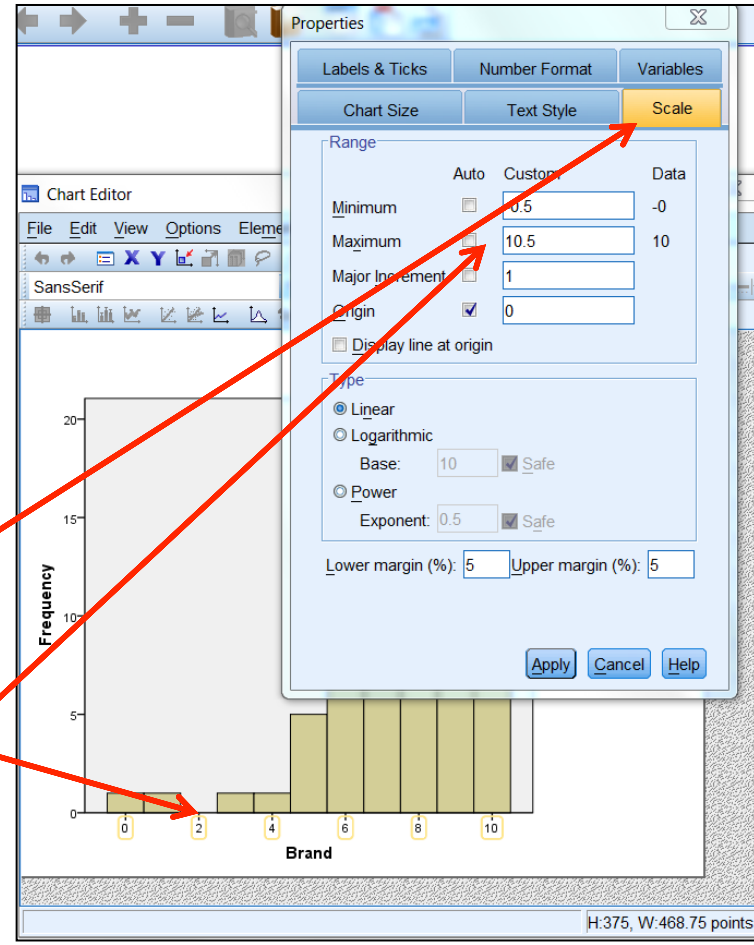
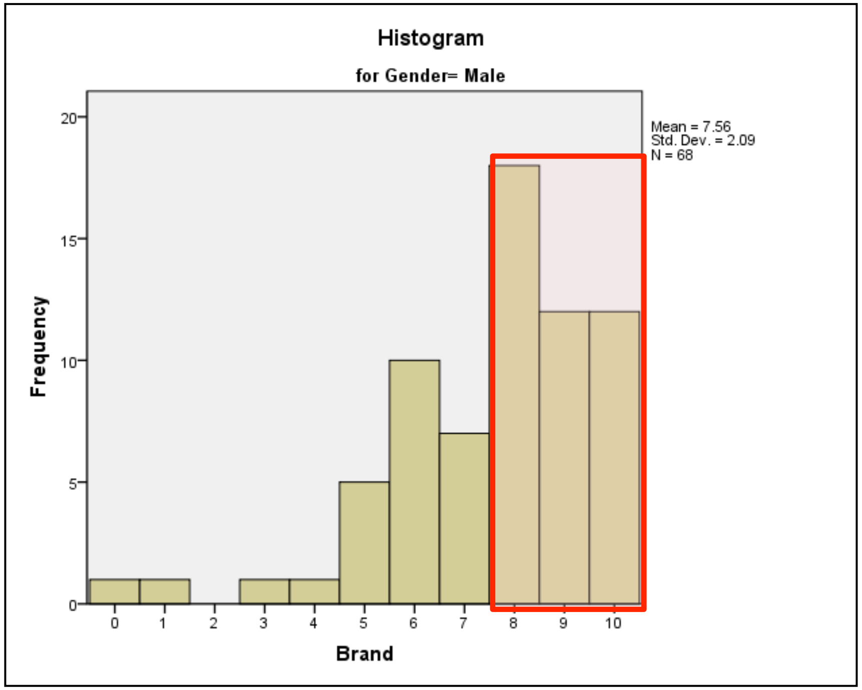
# Step 1: descriptive statistics

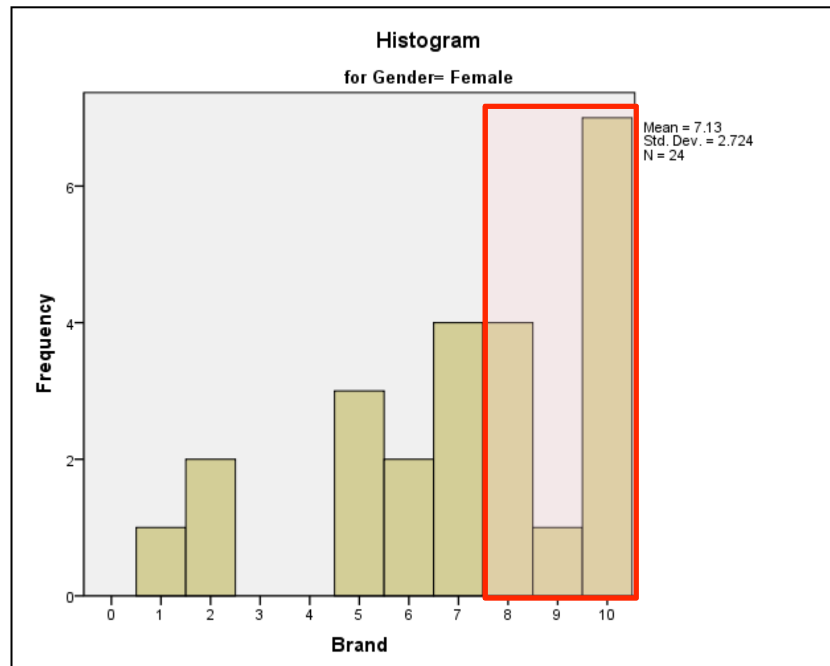
- ❑ Upload the file Smartphone.sav associated with this presentation
- ❑ Select Analyze – Descriptive Statistics – Explore…
- ❑ Select *Brand* in the Dependent List and *Gender* in the Factor List
- ❑ Select Plots… and choose None under boxplots and Histogram under descriptive
- ❑ Double click on each graph
- ❑ Double click on the values on the horizontal axis in the chart editor
- ❑ Select the Scale tab
- ❑ Change the Minimum to 0, the Maximum to 10 and the Major increment to 1



# Distribution of *Brand* by *Gender*




Both distributions clearly not normal with different sample sizes ⇒ non-parametric test needed




Shape of data different for Brand = 8, 9 and 10, but not in the same direction



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# A nonparametric test of association

- The data consist of counts of subjects with particular profiles
  - Profiles are formed by scale and categorical variables
  - Often referred to as a contingency table
- The test is whether there is an association between the categorical variables
- Equivalent to dropping pebbles at random in a grid where the row and column totals are already known

# Chi-squared ($\chi^2$) test

- Works with:
  - 2-way tables with known row and column totals, or
  - Measuring a sequence of observed values against expected values (not covered here)
- Based on calculating expected values for the table frequencies and comparing these with the observed values
- Only valid when most (≥80%) of the expected values are sufficiently large (≥5) and none has expected value <1
- Null hypothesis: the observed values are randomly distributed based on the expected values (i.e. there is no association between the two variables)

# Chi-squared test in SPSS

- ❑ Select *Analyze – Descriptive Statistics – Crosstabs…*
- ❑ Select *Gender* for the rows and *AgeCategory* for the columns
- ❑ Select *Statistics…* then *Chi-square* then *Continue*
- ❑ Select *Cells…* then *Expected* then *Continue*

Analysis is invalid because 15 out of 22 cells (way more than 20%) have an expected frequency less than 5

We need to combine some of the columns together and retest

**Gender * Brand Crosstabulation**

| | | | Brand | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| Gender | Male | Count | 1 | 1 | 0 | 1 | 1 | 5 | 10 | 7 | 18 | 12 | 12 | 68 |
| | | Expected Count | .7 | 1.5 | 1.5 | .7 | .7 | 5.9 | 8.9 | 8.1 | 16.3 | 9.6 | 14.0 | 68.0 |
| | Female | Count | 0 | 1 | 2 | 0 | 0 | 3 | 2 | 4 | 4 | 1 | 7 | 24 |
| | | Expected Count | .3 | .5 | .5 | .3 | .3 | 2.1 | 3.1 | 2.9 | 5.7 | 3.4 | 5.0 | 24.0 |
| Total | | Count | 1 | 2 | 2 | 1 | 1 | 8 | 12 | 11 | 22 | 13 | 19 | 92 |
| | | Expected Count | 1.0 | 2.0 | 2.0 | 1.0 | 1.0 | 8.0 | 12.0 | 11.0 | 22.0 | 13.0 | 19.0 | 92.0 |


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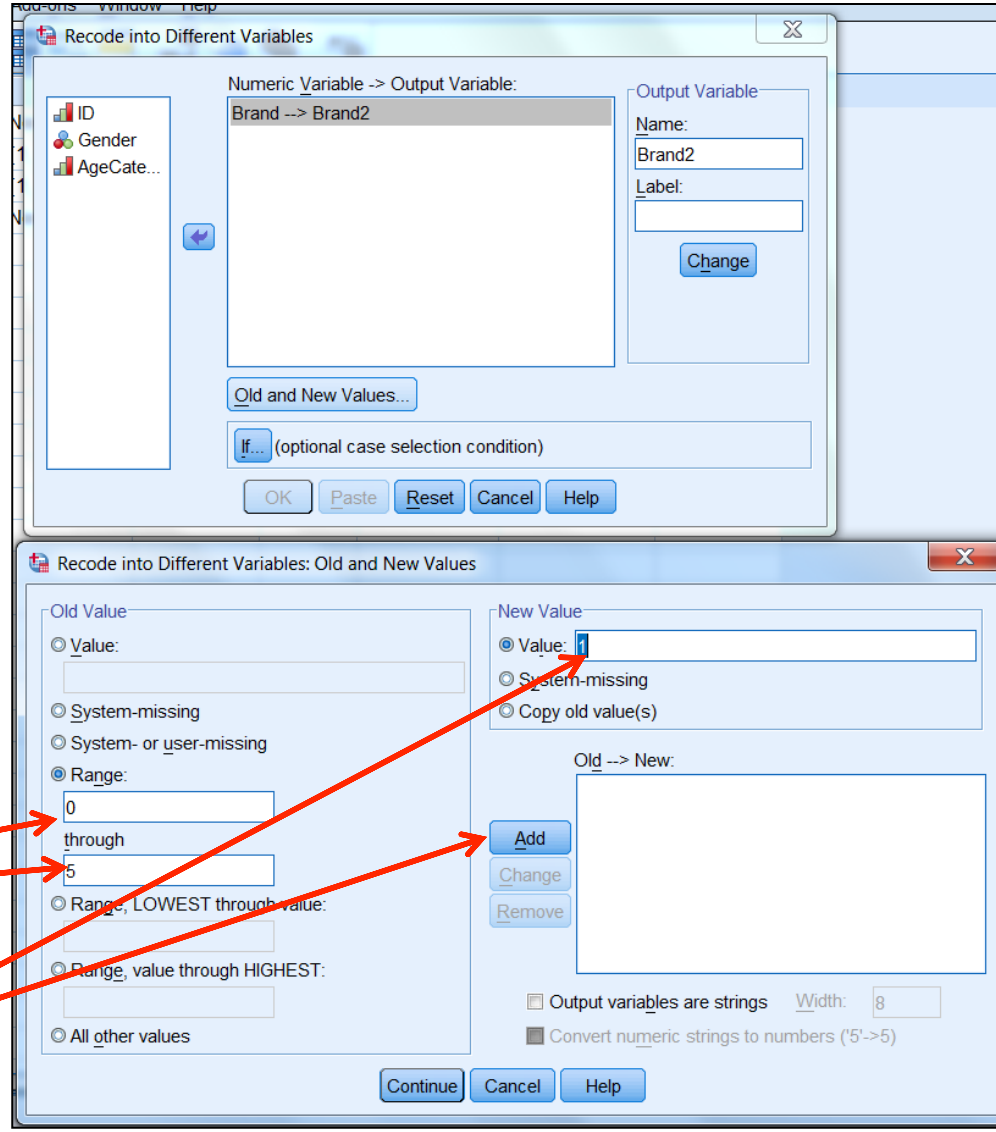
# Recode *Brand* into a new variable

- Select Transform – Recode into Different Variables…
- Select *Brand* from the list
- Enter *Brand2* as the output variable name and press Change
- Select Old and New Values…
- Under Old Value, select Range and enter the values 0 and 5
- Under New Value, enter 1 and select Add





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- Repeat with the range 6 through 7 going to 2
- Recode the value 8 as 3, 9 as 4, and 10 as 5
- On the Variable View, change the number of decimal places of *Brand2* to 0 and its data type to Ordinal
- Add values to *Brand2* to explain these settings
- Re-run the chi-squared test by changing the variable from *Brand* to *Brand2* and keeping all the other options the same

Analysis still not valid as 3 out of 10 cells (>20%) still have expected frequency <5

**Gender * Brand2 Crosstabulation**

| | | | Brand2 | | | | | Total |
|---|---|---|---|---|---|---|---|---|
| | | | 0-5 | 6-7 | 8 | 9 | 10 | |
| Gender | Male | Count | 9 | 17 | 18 | 12 | 12 | 68 |
| | | Expected Count | 11.1 | 17.0 | 16.3 | 9.6 | 14.0 | 68.0 |
| | Female | Count | 6 | 6 | 4 | 1 | 7 | 24 |
| | | Expected Count | 3.9 | 6.0 | 5.7 | 3.4 | 5.0 | 24.0 |
| Total | | Count | 15 | 23 | 22 | 13 | 19 | 92 |
| | | Expected Count | 15.0 | 23.0 | 22.0 | 13.0 | 19.0 | 92.0 |

Result not significant as P-value for chi-squared >0.05

**Chi-Square Tests**

| | Value | df | Asymp. Sig. (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 5.640[a] | 4 | .228 |
| Likelihood Ratio | 6.096 | 4 | .192 |
| Linear-by-Linear Association | .183 | 1 | .669 |
| N of Valid Cases | 92 | | |

a. 3 cells (30.0%) have expected count less than 5. The minimum expected count is 3.39.

Recoding again and re-running would probably not improve the result

# Fisher's exact test

- Applies to 2x2 contingency tables
- Works with smaller samples than chi-squared:
  - Sample size > 40 ⇒ chi-squared can be used
  - Sample size between 20 and 40 and the smallest expected frequency ≥ 5, ⇒ chi-squared can be used
  - Otherwise Fisher's exact test **must** be used
- A one-sided test with a 2-sided normal approximation
- Provided automatically by SPSS when you cross-tabulate and select chi-squared


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- Go back to the first data set
- Select Transform - Recode into Different Variable to recode *Housekeeping* into *Housekeeping2* with:
  - 0, 1 and 2 recoded as 1
  - 3 recoded as 2
  - (We are leaving out 4)
- Change *Housekeeping2* so that it has zero decimal places and the values are as above
- Select Analyze – Descriptive Statistics – Crosstabs and choose Group and Housekeeping2 and the chi-squared test

There are 82 valid cases so chi-squared would be valid here

Chi-squared P-value is 0.011 – slightly weaker than the Mann-Whitney U test result (0.007)

Fisher's exact P-value is 0.010 for one sided ($H_0$: Housekeeping is the same or worse) and 0.014 for 2-sided

**Group * Housekeeping2 Crosstabulation**

| | | | Housekeeping2 | | |
|---|---|---|---|---|---|
| | | | Still keeps house | No longer keeps house | Total |
| Group | Control | Count | 14 | 21 | 35 |
| | | Expected Count | 19.6 | 15.4 | 35.0 |
| | Treatment | Count | 32 | 15 | 47 |
| | | Expected Count | 26.4 | 20.6 | 47.0 |
| Total | | Count | 46 | 36 | 82 |
| | | Expected Count | 46.0 | 36.0 | 82.0 |

**Chi-Square Tests**

| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
|---|---|---|---|---|---|
| Pearson Chi-Square | 6.425[a] | 1 | .011 | | |
| Continuity Correction[b] | 5.335 | 1 | .021 | | |
| Likelihood Ratio | 6.477 | 1 | .011 | | |
| Fisher's Exact Test | | | | .014 | .010 |
| Linear-by-Linear Association | 6.347 | 1 | .012 | | |
| N of Valid Cases | 82 | | | | |

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 15.37.
b. Computed only for a 2x2 table



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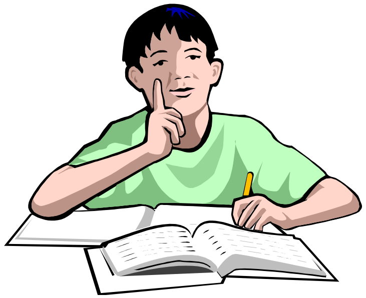

# Activities

1. Run a chi-squared test with the three measures of ADL against the treatment *Group* with the first data set, recoding each measure into fewer categories if necessary. Are the results more or less significant? Explain.
2. Run a Mann-Whitney U test of *Brand* against *Gender* with the second data set. Are the results more or less significant? Explain.
3. Describe *Brand* against *AgeCategory* (e.g. a boxplot or multiple histograms), decide on the best way to test this association, carry out the test, ensuring it is valid, interpret your findings, repeating if necessary.


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# Recap

We have covered:

- What are nonparametric methods?
- When should you use them?
- Overview of nonparametric methods
- Comparing two groups:
  - Mann-Whitney U test
- Cross-tabulating two variables:
  - Chi-squared test of association
  - Fisher's exact test



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# Bibliography

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