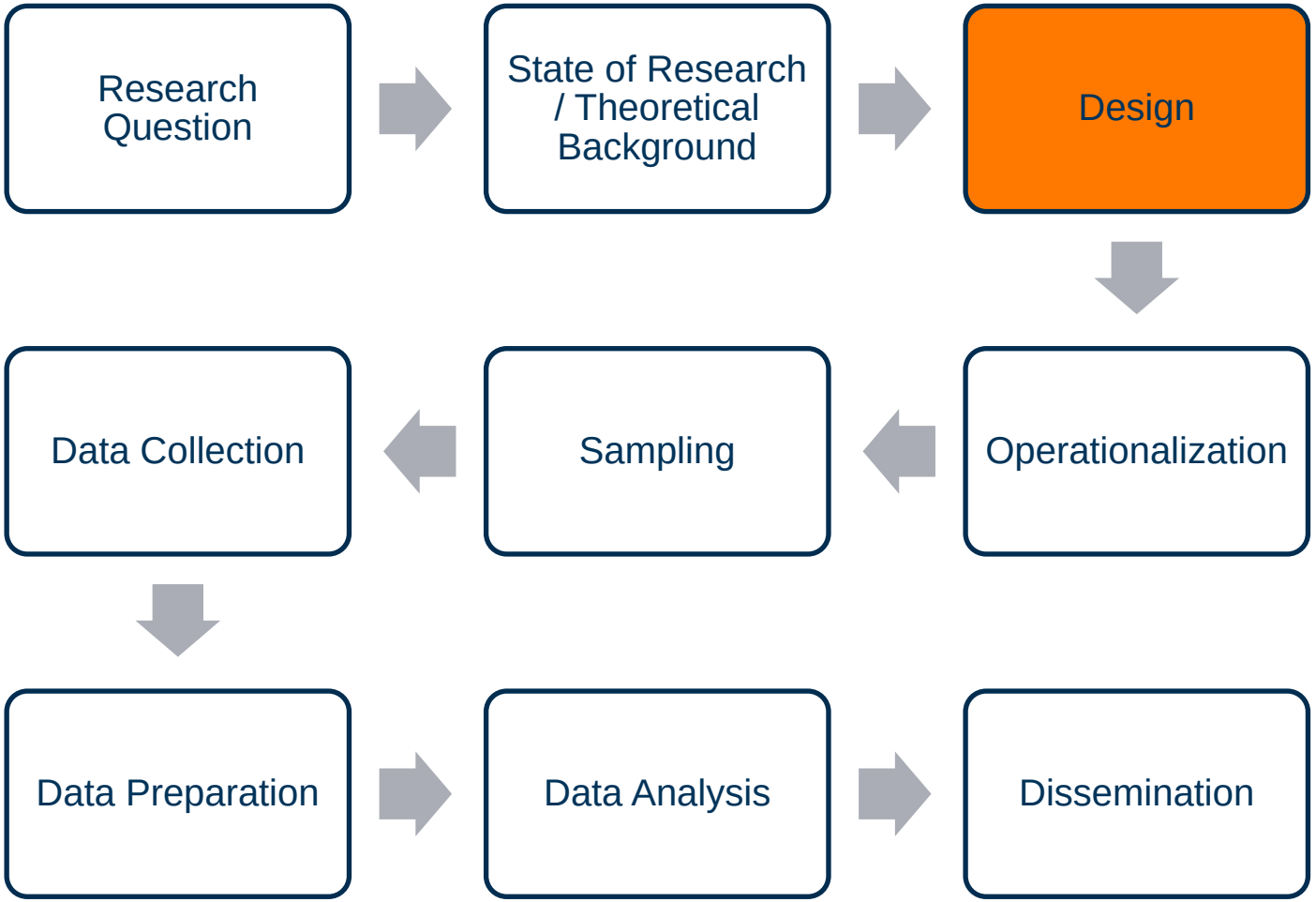
# Workshop Research Methods and Statistical Analysis

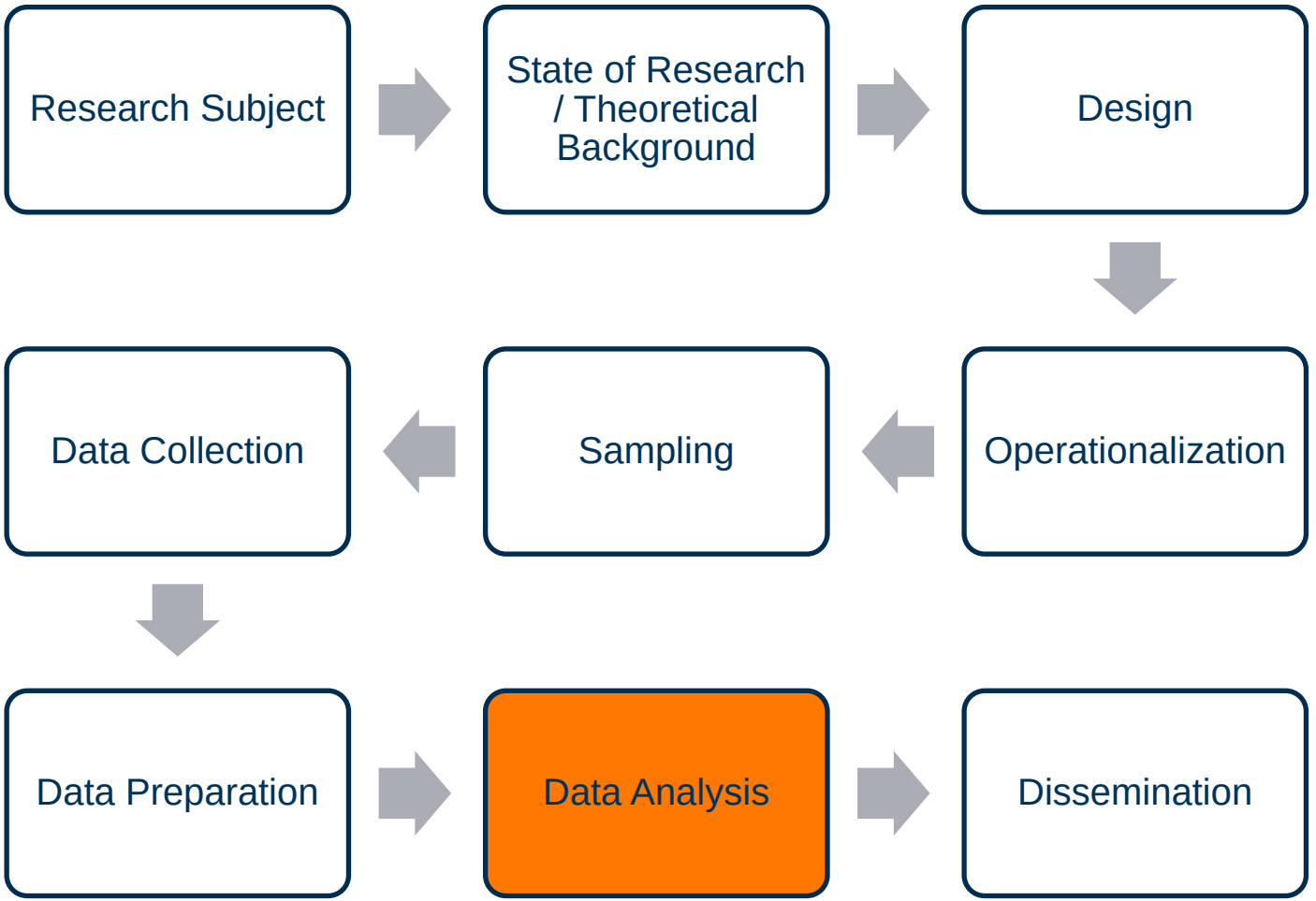
## Session 2 – Data Analysis

Sandra Poeschl

# Research process



# Research process



# Designs we will deal with

- Experimental designs
  - Quantitative
  - Empirical
  - Explanatory
  - Sample study
- Frequency of measurements as an effect on choice of statistical tests
  - Cross-sectional
  - Repeated measures

# Agenda

- Descriptive and inferential statistics
- Indication (which test?)
- Two groups (experimental / control)
  - t-Test for independent and dependent samples
- One-way (1 factor)
  - One-way ANOVA
- Multi-factorial (several factors)
  - Two-way ANOVA, within-between subjects

# DESCRIPTIVE AND INFERENTIAL STATISTICS

# Descriptive vs. inferential

**Descriptive statistics**

- Reporting sample data
  - Measures of location (arithmetic mean, median, mode)
  - Measures of spread (range, variance, standard deviation)
  - Correlations
  - frequencies
- Reported in text, also tables, graphs

**Inferential statistics**

- Inference from sample data to population effects
- Parameter estimation
  - Point & interval estimation
- Testing hypotheses
- Significance tests

# Descriptive vs. inferential in explanatory studies

**Descriptive statistics**

- Decribing the sample
- Complementary presentation of sample statistics for tested hypotheses

**Inferential statistics**

- Testing hypotheses
- Significance tests

# WHICH TEST?

# How do I choose the appropriate test?

- Type of hypothesis
  - **Difference**, correlation, change
- Number of groups / treatments or variables
- Levels of measurement
  - nominal, ordinal, interval / ratio

# Level of measurement

| | Affiliation to Category | Rank order | Same differences between gradings | Absolute zero |
|---|---|---|---|---|
| Nominal | + | | | |
| Ordinal | + | + | | |
| Interval | + | + | + | |
| Ratio | + | + | + | + |

Nominal: eye color
Ordinal: level of education
Interval: opinion, date
Ratio: age

# TWO GROUPS

# 2-Groups (Treatment / Control)

- 1 IV, dichotomous,
  1 DV, metric
  (univariate)
  - Cross-sectional or repeated measures
  - t-Test (independent / dependent samples)

| No sound | Spatial sound |
| --- | --- |
| | |

IV: sound (no sound/spatial sound
DV: error rate in an orientation task

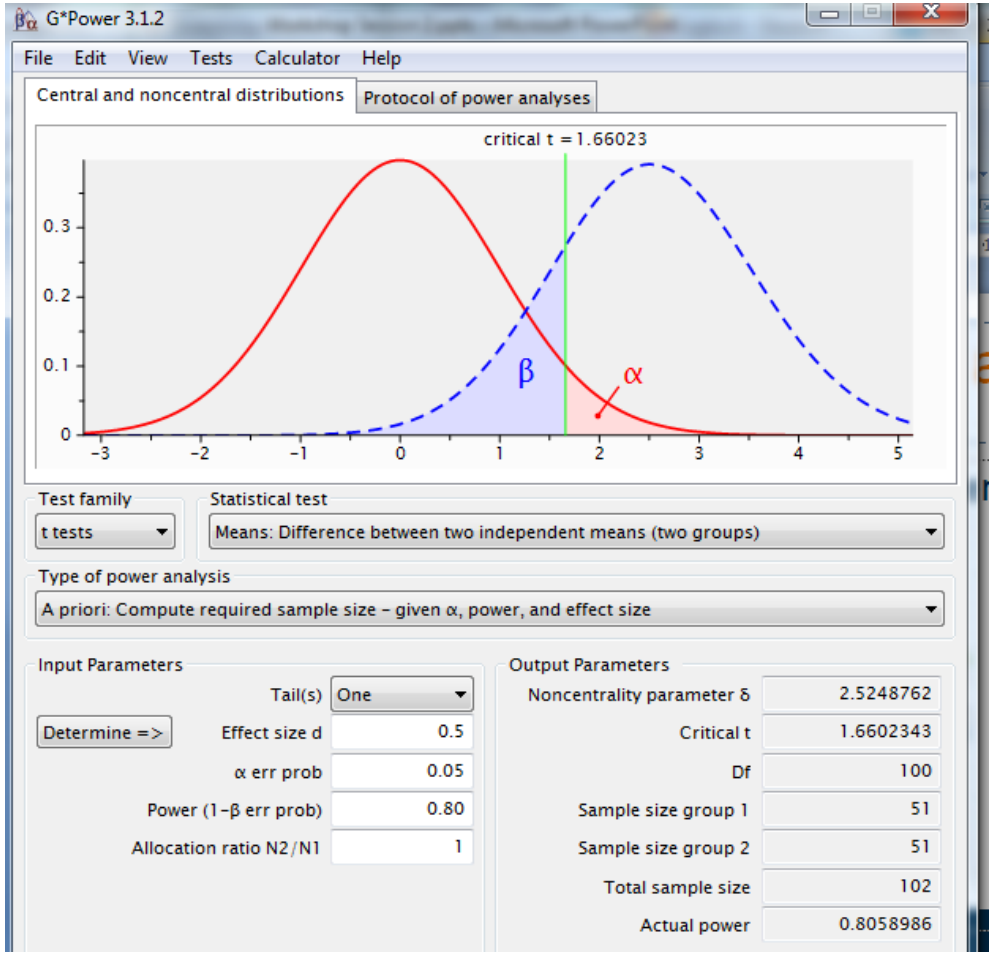
# Which test?

- H1: Integrating spatial sound in a VE leads to lower error rates in an orientation task than a no-sound display.
- Hypothesis on a difference
- Independent samples
- 1 independent variable, 2 groups (no sound / spatial sound)
- 1 dependent variable (ratio)
- → Student‘s t-Test

# Requirements Student‘s t-Test

- Level of measurement of DV at least interval
- Normal distribution of DV
- Variances $\sigma_A$ and $\sigma_B$ are equal
- Levene‘s Test for equality of variances, corrections of df.
- Sample within groups should be very similar, $n_A = n_B > 30$.
- Non-parametric alternative: Mann-Whitney U-Test

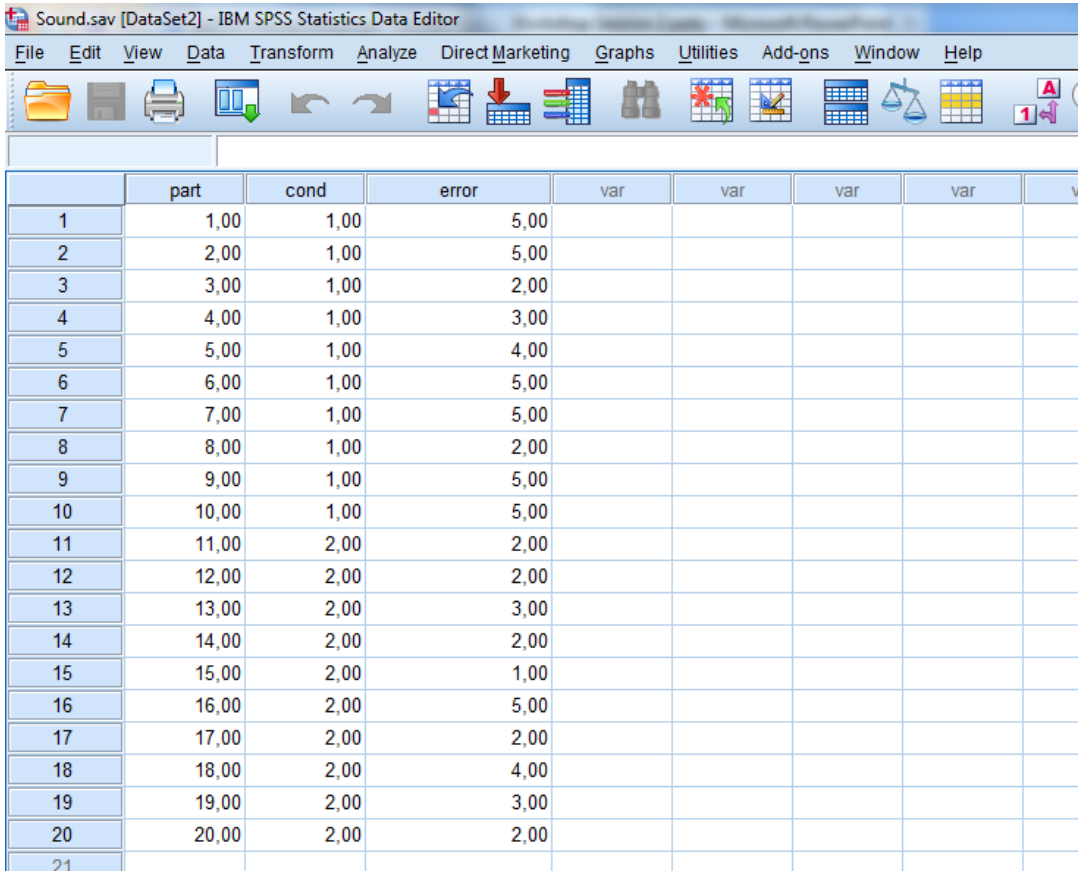
# A priori power analysis




- Test family: t tests
- Statistical test: Means: Differences between two independent means
- Type of power analysis: A priori
- Medium effect size d = .5
- α = .05
- 1-β = .80
- Allocation ratio = 1

- Sample size / group = 51
- Total sample size = 102

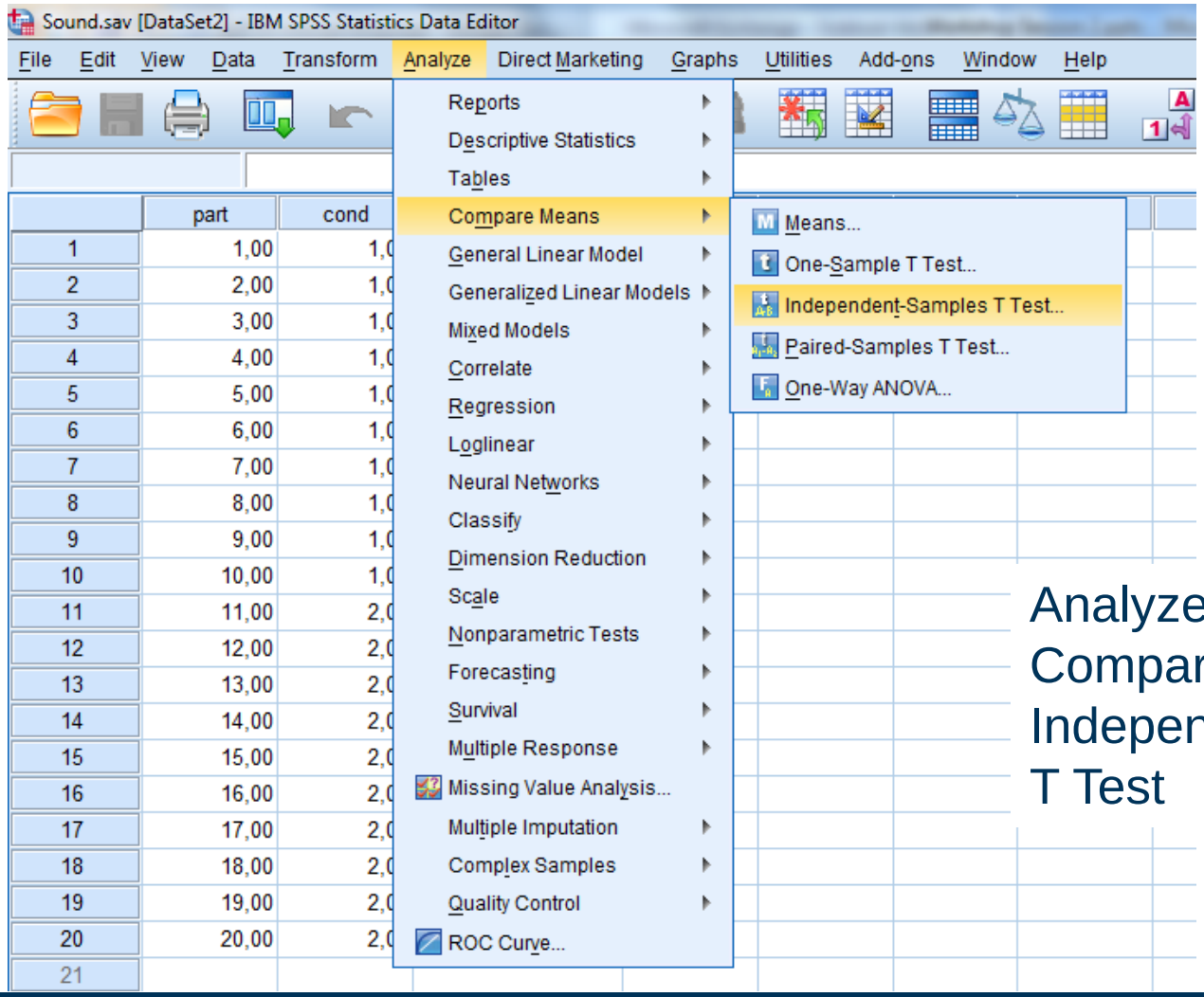
# The data set




| | part | cond | error | var | var | var | var |
|---|---|---|---|---|---|---|---|
| 1 | 1,00 | 1,00 | 5,00 | | | | |
| 2 | 2,00 | 1,00 | 5,00 | | | | |
| 3 | 3,00 | 1,00 | 2,00 | | | | |
| 4 | 4,00 | 1,00 | 3,00 | | | | |
| 5 | 5,00 | 1,00 | 4,00 | | | | |
| 6 | 6,00 | 1,00 | 5,00 | | | | |
| 7 | 7,00 | 1,00 | 5,00 | | | | |
| 8 | 8,00 | 1,00 | 2,00 | | | | |
| 9 | 9,00 | 1,00 | 5,00 | | | | |
| 10 | 10,00 | 1,00 | 5,00 | | | | |
| 11 | 11,00 | 2,00 | 2,00 | | | | |
| 12 | 12,00 | 2,00 | 2,00 | | | | |
| 13 | 13,00 | 2,00 | 3,00 | | | | |
| 14 | 14,00 | 2,00 | 2,00 | | | | |
| 15 | 15,00 | 2,00 | 1,00 | | | | |
| 16 | 16,00 | 2,00 | 5,00 | | | | |
| 17 | 17,00 | 2,00 | 2,00 | | | | |
| 18 | 18,00 | 2,00 | 4,00 | | | | |
| 19 | 19,00 | 2,00 | 3,00 | | | | |
| 20 | 20,00 | 2,00 | 2,00 | | | | |
| 21 | | | | | | | |

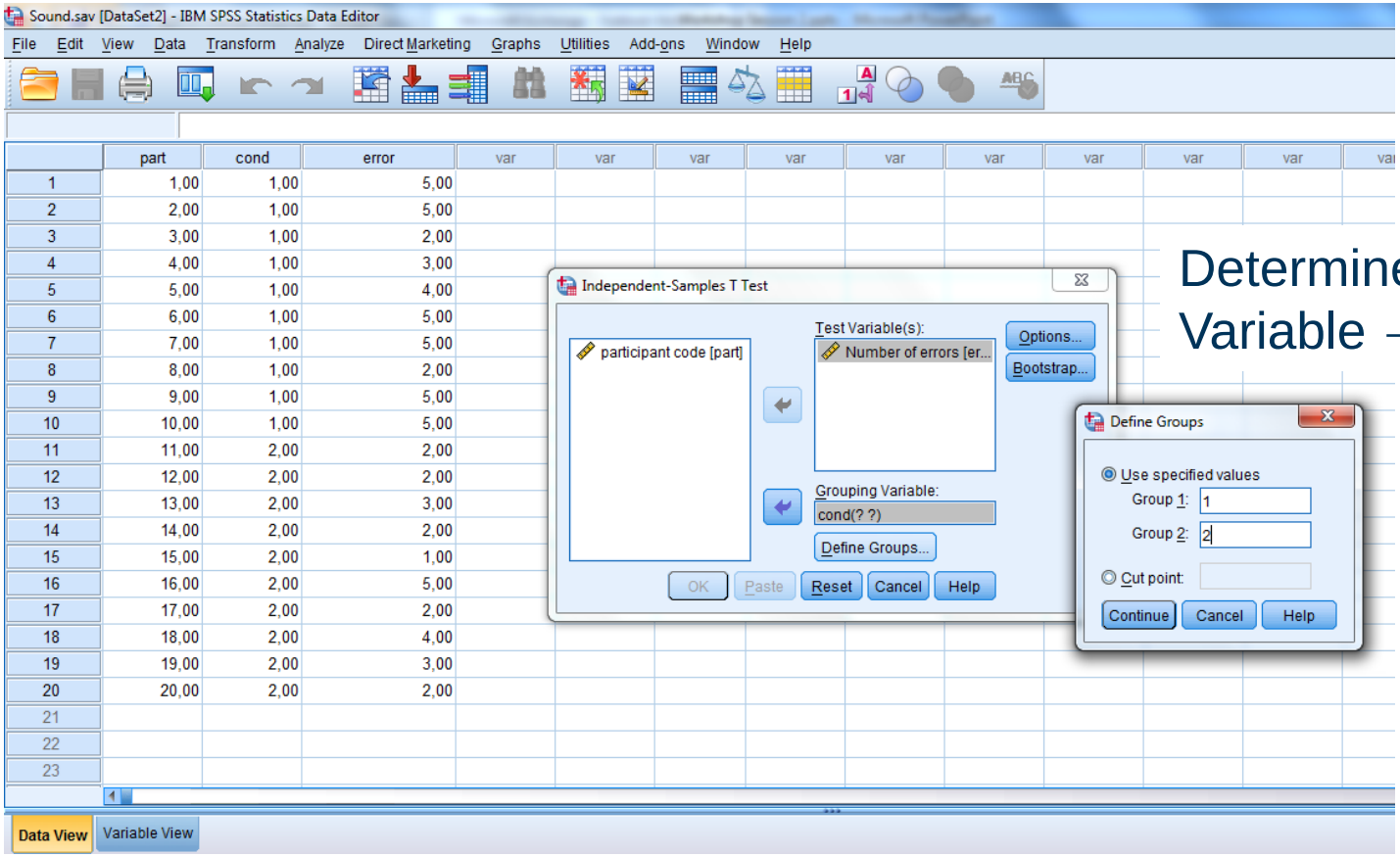
- One case per row
- One variable per column
- Part = participant #
- Cond = condition
- Error = error rate

# Independent Samples t-Test




Analyze /
Compare Means /
Independent-Samples
T Test

# Independent Samples t-Test




Determine Grouping Variable → Condition

# SPSS Output

**Group Statistics**

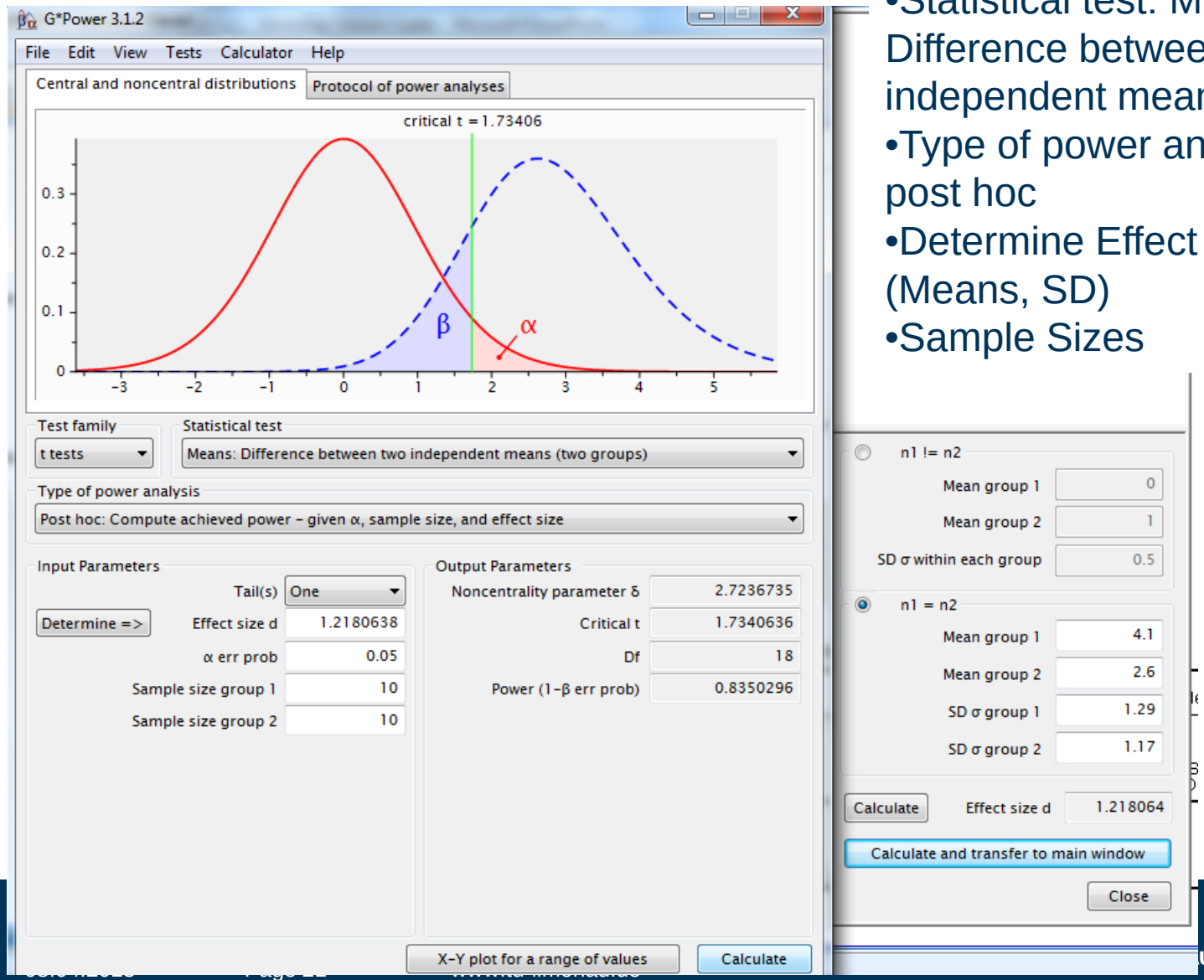
| | condition | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Number of errors | no sound | 10 | 4,1000 | 1,28668 | ,40689 |
| | spatial sound | 10 | 2,6000 | 1,17379 | ,37118 |

**Independent Samples Test**

| | | Levene's Test for Equality of Variances | | t-test for Equality of Means | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | 95% Confidence Interval of the Difference | |
| | | F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | Lower | Upper |
| Number of errors | Equal variances assumed | ,321 | ,578 | 2,724 | 18 | ,014 | 1,50000 | ,55076 | ,34290 | 2,65710 |
| | Equal variances not assumed | | | 2,724 | 17,850 | ,014 | 1,50000 | ,55076 | ,34221 | 2,65779 |

# Effect size

- Test family: t tests
- Statistical test: Means: Difference between 2 independent means
- Type of power analysis: post hoc
- Determine Effect Size (Means, SD)
- Sample Sizes



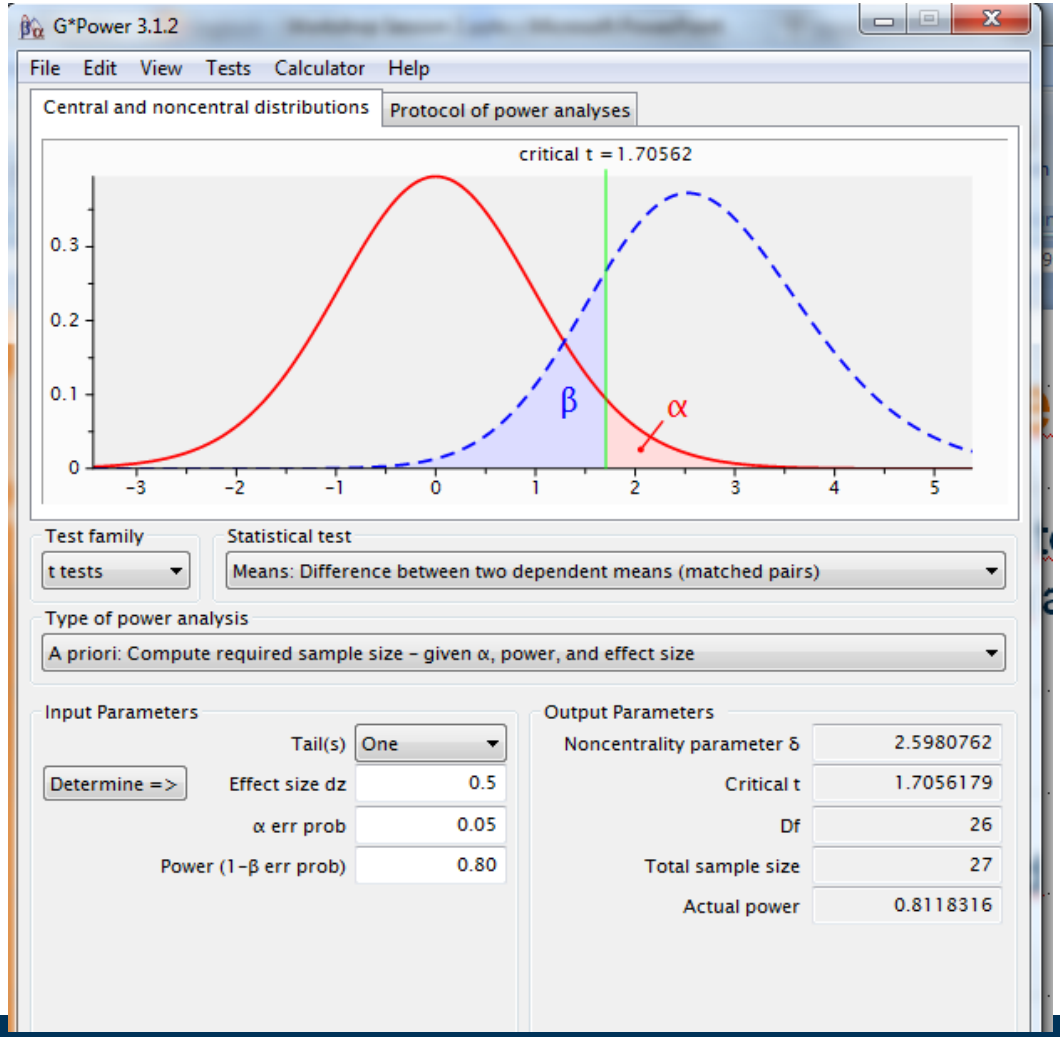
# Results

- H1: Integrating spatial sound in a VE leads to lower error rates in an orientation task than a no-sound display.
- $M_{\text{no sound}} = 4.10$ (SD = 1.29; n = 10)
- $M_{\text{spatial sound}} = 2.6$ (SD = 1.17; n = 10)
- d = 1.22 (large)
- t = 2.72; df = 18; $p < .05$
- $\rightarrow H_0$ is rejected

# Which test?

- H1: Integrating spatial sound in a VE leads to lower error rates in an orientation task than a no-sound display.
- Hypothesis on a difference
- Dependent samples
- 1 independent variable, 2 groups (no sound / spatial sound), within-subjects
- 1 dependent variable (ratio)
- → Student‘s t-Test for paired samples

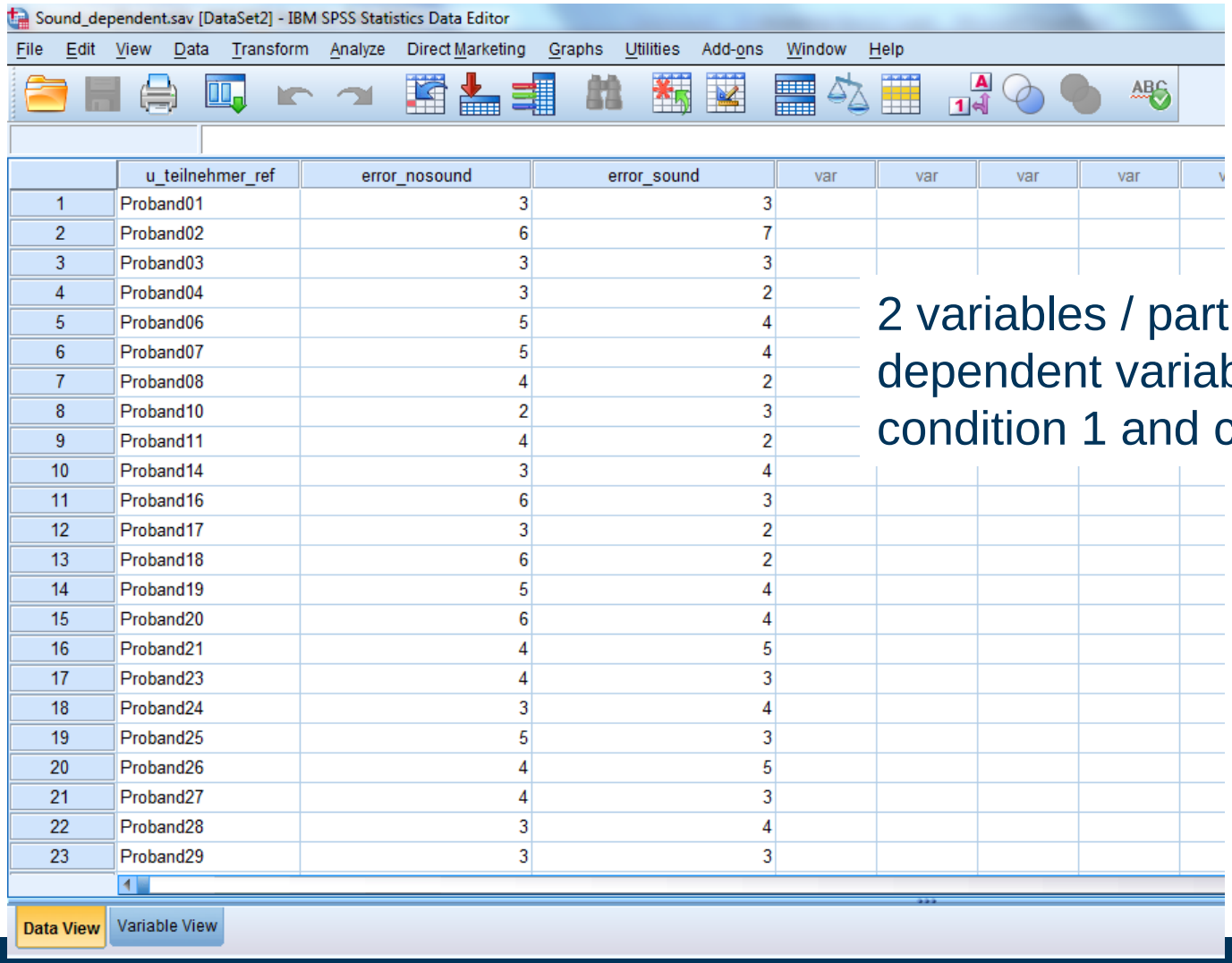
# A priori power analysis




- Test family: Means: Difference between two dependent means
- Type of power analysis: A priori
- Medium effect size d = .5
- α = .05
- 1-β = .80

Total sample size = 27

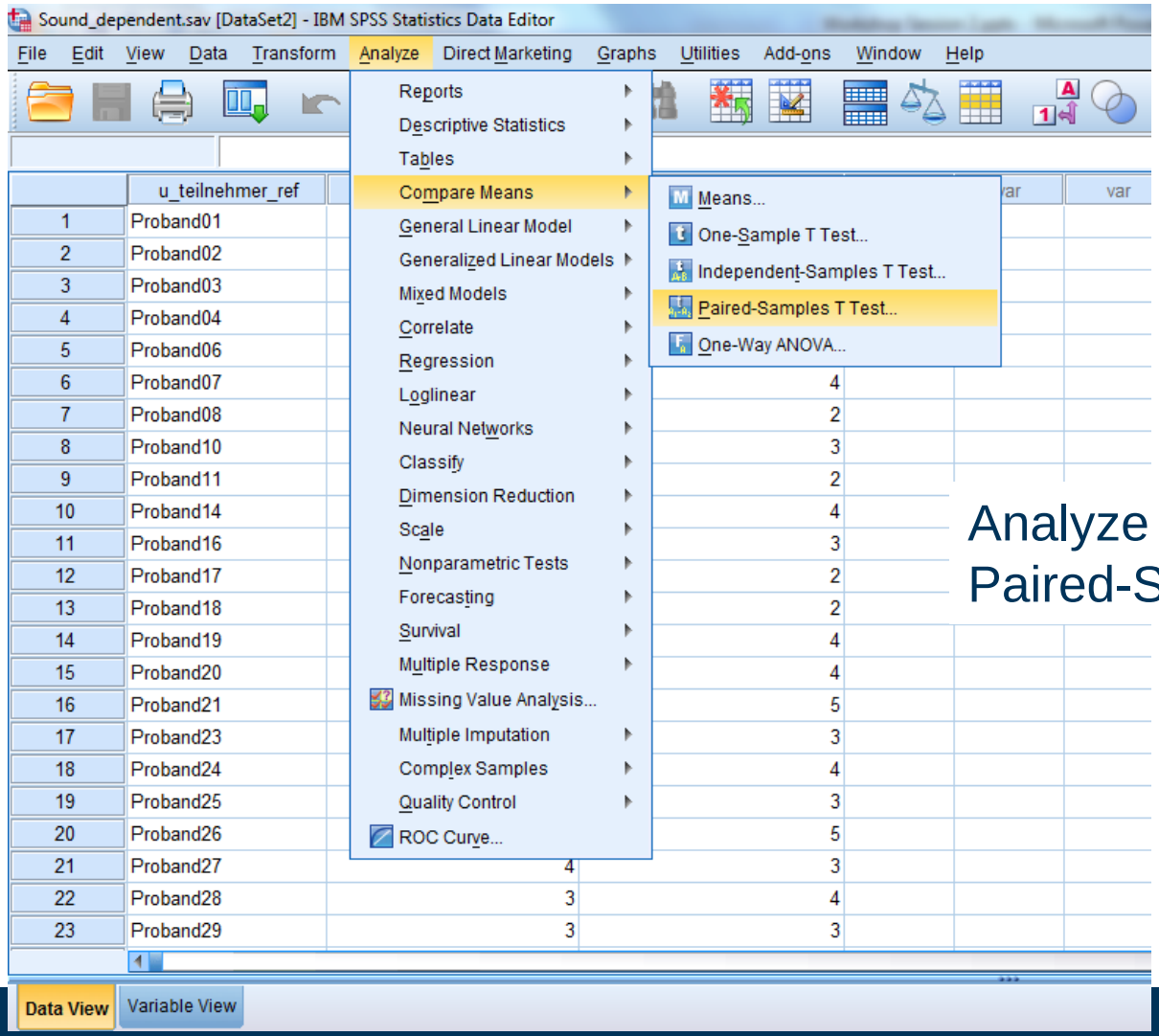
# Data Set




| | u_teilnehmer_ref | error_nosound | error_sound | var | var | var | var |
|---|---|---|---|---|---|---|---|
| 1 | Proband01 | 3 | 3 | | | | |
| 2 | Proband02 | 6 | 7 | | | | |
| 3 | Proband03 | 3 | 3 | | | | |
| 4 | Proband04 | 3 | 2 | | | | |
| 5 | Proband06 | 5 | 4 | | | | |
| 6 | Proband07 | 5 | 4 | | | | |
| 7 | Proband08 | 4 | 2 | | | | |
| 8 | Proband10 | 2 | 3 | | | | |
| 9 | Proband11 | 4 | 2 | | | | |
| 10 | Proband14 | 3 | 4 | | | | |
| 11 | Proband16 | 6 | 3 | | | | |
| 12 | Proband17 | 3 | 2 | | | | |
| 13 | Proband18 | 6 | 2 | | | | |
| 14 | Proband19 | 5 | 4 | | | | |
| 15 | Proband20 | 6 | 4 | | | | |
| 16 | Proband21 | 4 | 5 | | | | |
| 17 | Proband23 | 4 | 3 | | | | |
| 18 | Proband24 | 3 | 4 | | | | |
| 19 | Proband25 | 5 | 3 | | | | |
| 20 | Proband26 | 4 | 5 | | | | |
| 21 | Proband27 | 4 | 3 | | | | |
| 22 | Proband28 | 3 | 4 | | | | |
| 23 | Proband29 | 3 | 3 | | | | |

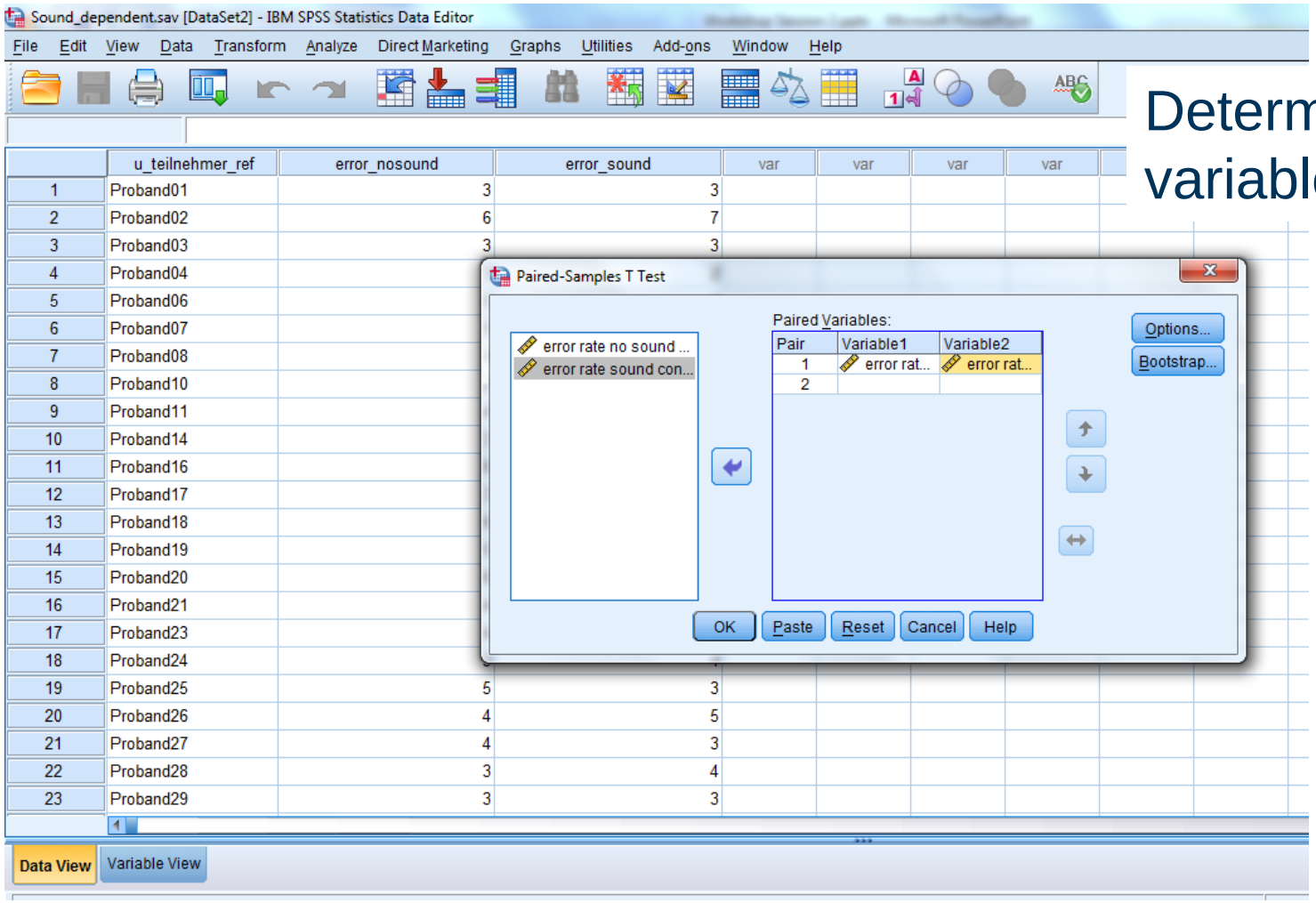
2 variables / participant: dependent variable for condition 1 and condition 2

# Paired-Samples t-Test




Analyze / Compare Means / Paired-Samples T-Test

# Paired-Samples t-Test




Determine paired variables

# SPSS Output

**Paired Samples Statistics**

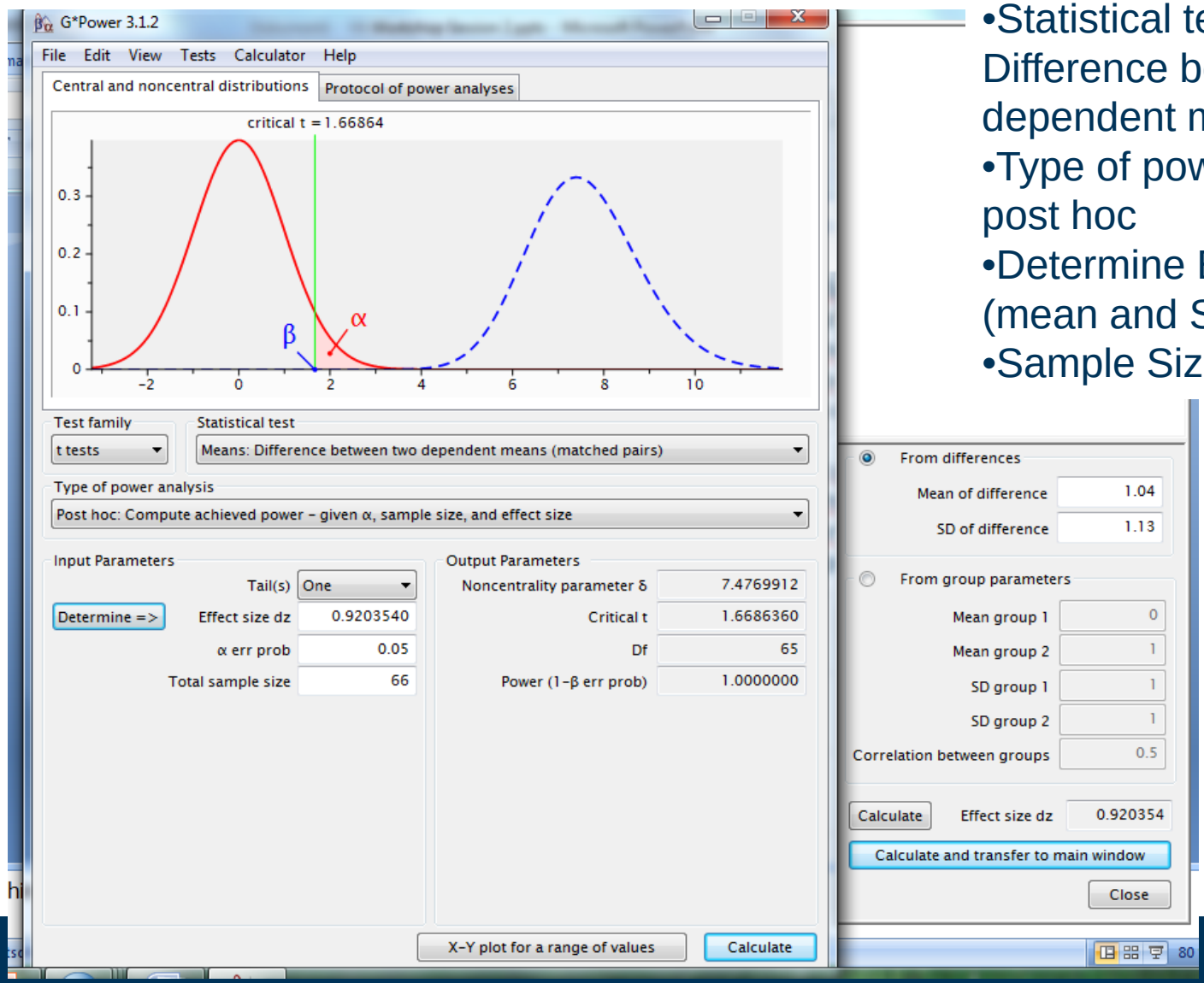
| | | Mean | N | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| Pair 1 | error rate no sound condition | 4,19 | 66 | 1,282 | ,158 |
| | error rate sound condition | 3,15 | 66 | 1,358 | ,167 |

**Paired Samples Test**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference Lower | Upper | | | |
| Pair 1 | error rate no sound condition - error rate sound condition | 1,035 | 1,128 | ,139 | ,758 | 1,313 | 7,455 | 65 | ,000 |

# Effect size

- Test family: t tests
- Statistical test: Means: Difference between 2 dependent means
- Type of power analysis: post hoc
- Determine Effect Size (mean and SD of difference)
- Sample Size



# Results

- H1: Integrating spatial sound in a VE leads to lower error rates in an orientation task than a no-sound display.
- $M_{\text{no sound}} = 4.19$ (SD = 1.28; n = 66)
- $M_{\text{spatial sound}} = 3.15$ (SD = 1.36; n = 66)
- d = .92 (large)
- t = 7.46; df = 65; $p < .0001$
- $\rightarrow H_0$ is rejected

# ONE-WAY (1 FACTOR)

# One-way ANOVA

- One-way, univariate:
  - 1 IV, more than 2 levels (nominal), 1 DV (metric)
  - Cross-sectional or repeated measures
  - One-way, univariate ANOVA (repeated measures)

| FOR 20 | FOR 90 | FOR 270 |
|---|---|---|
| | | |

IV: FOR (20 degrees/90 degrees/270 degrees)
DV: error rate in search task

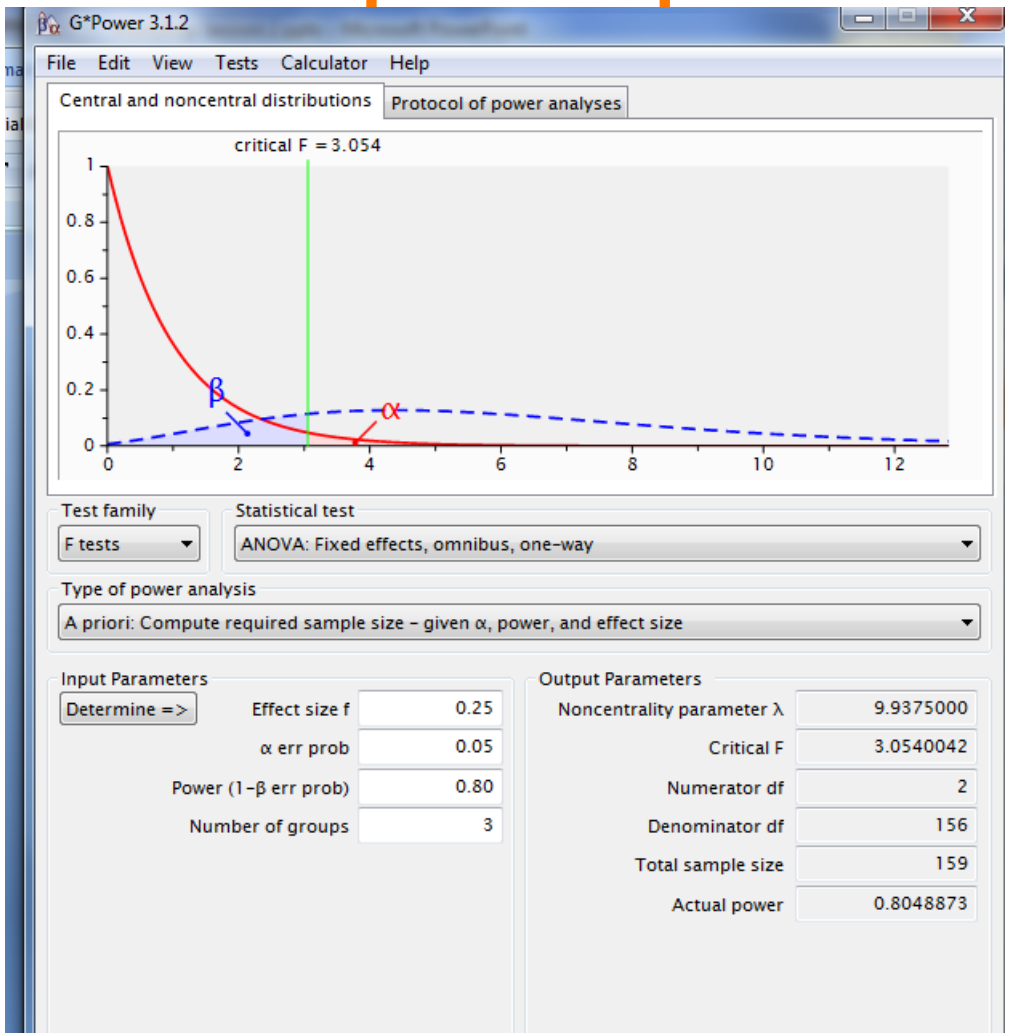
# Which test?

- H1: Higher field of regard leads to reduced error rate in a search task.
- Hypothesis on a difference
- Independent samples / between-subjects
- 1 independent variable, 3 groups (FOR 20 / FOR90 / FOR270)
- 1 dependent variable (ratio)
- → One-way univariate ANOVA

# Requirements ANOVA

- DV = interval / ratio
- normal distribution for DV
- N > 20 per cell
- $N_{max} / n_{min} < 1.5$
- Homogeneity of variances between samples
- Non-parametric alternative: Kruskal-Wallis-Test

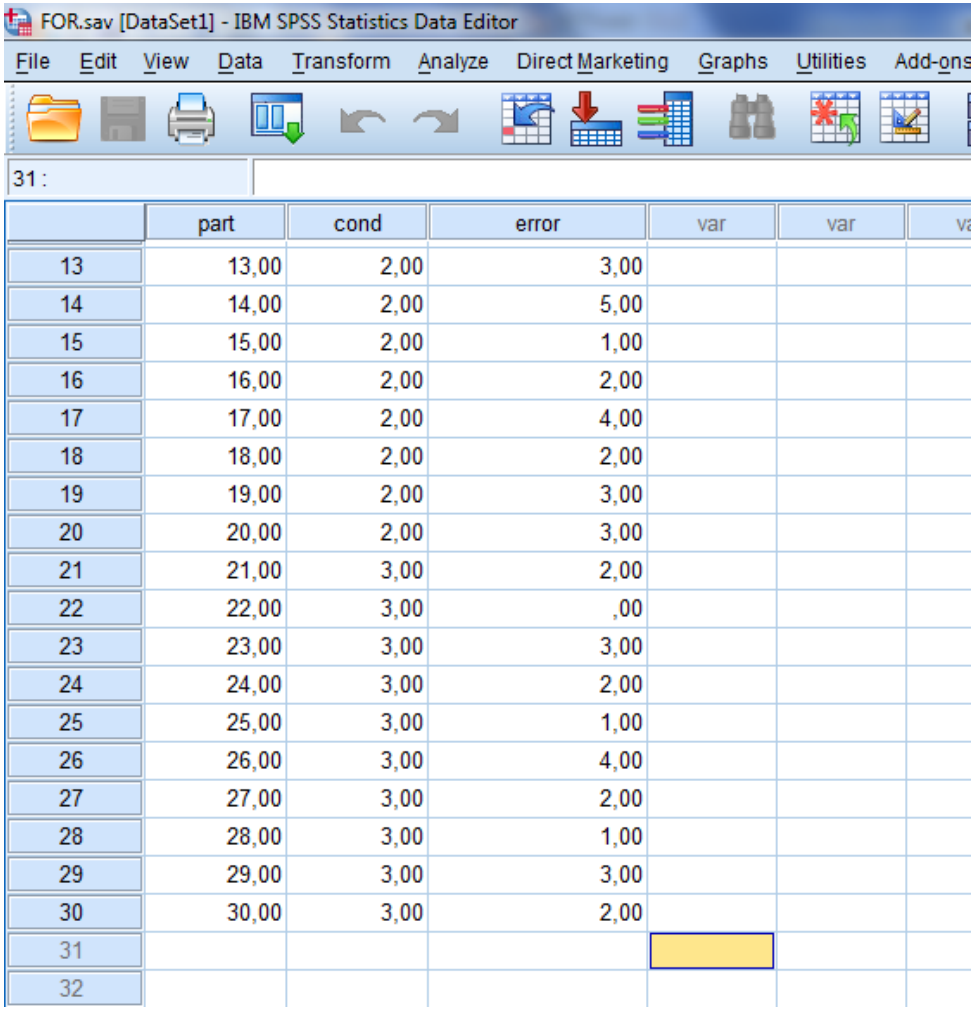
# A priori power analysis




- Test family: F tests
- Statistical test: ANOVA, fixed effects, omnibus, one-way
- Type of power analysis: A priori
- Medium effect size f = .25
- α = .05
- 1-β = .80
- Number of groups = 3

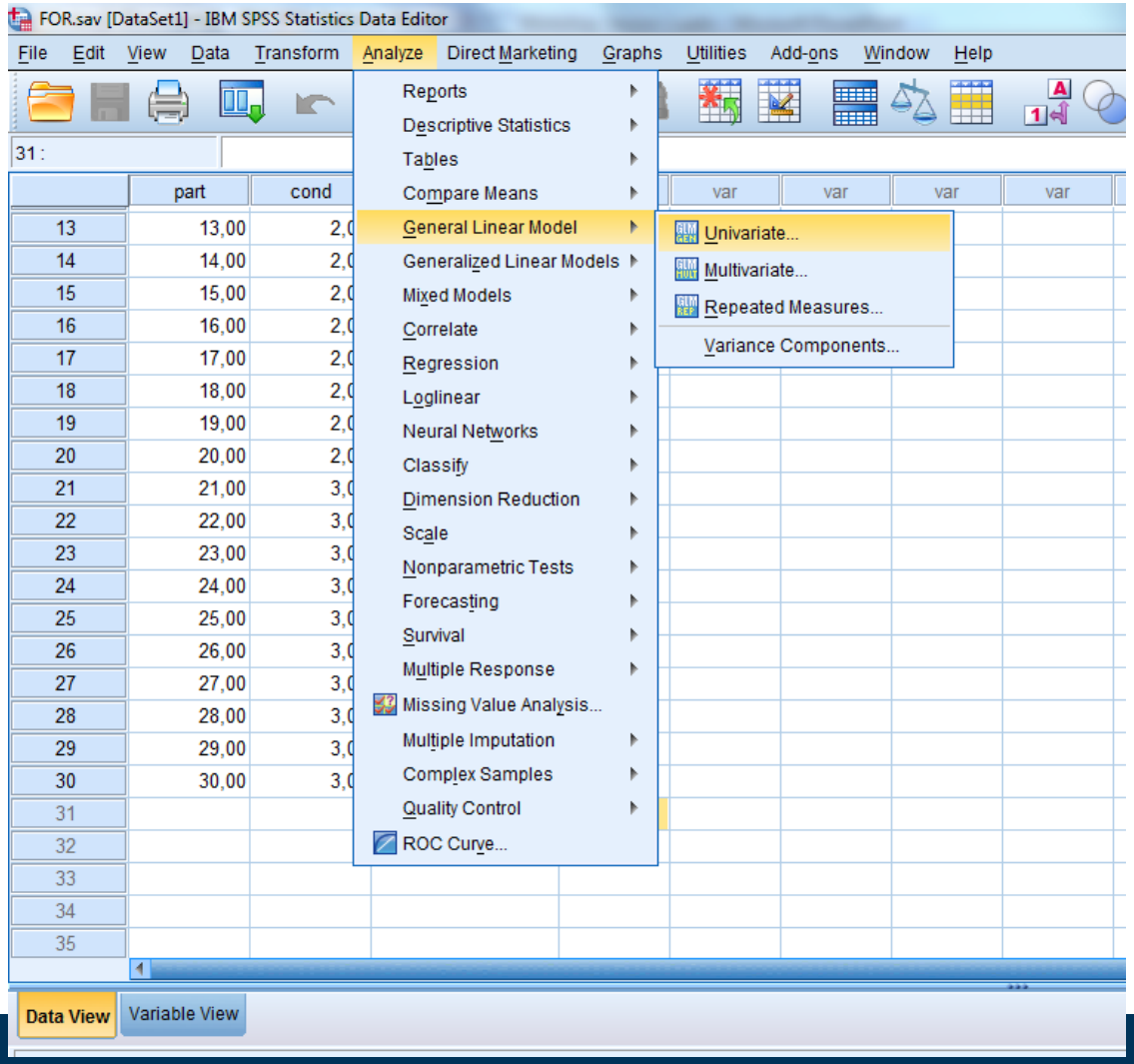
- Total sample size = 159

# Data Set



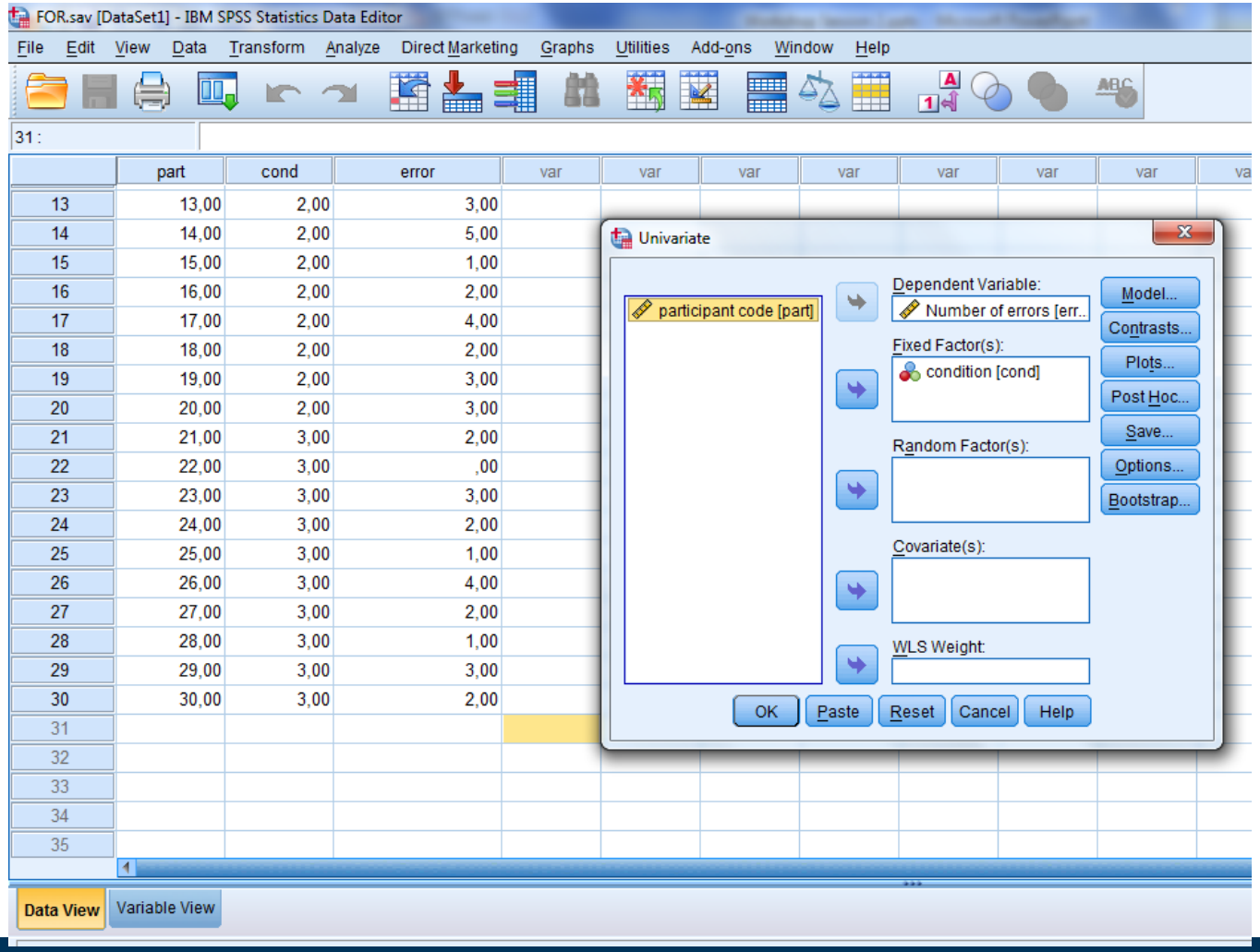

| | part | cond | error | var | var | va |
|---|---|---|---|---|---|---|
| 13 | 13,00 | 2,00 | 3,00 | | | |
| 14 | 14,00 | 2,00 | 5,00 | | | |
| 15 | 15,00 | 2,00 | 1,00 | | | |
| 16 | 16,00 | 2,00 | 2,00 | | | |
| 17 | 17,00 | 2,00 | 4,00 | | | |
| 18 | 18,00 | 2,00 | 2,00 | | | |
| 19 | 19,00 | 2,00 | 3,00 | | | |
| 20 | 20,00 | 2,00 | 3,00 | | | |
| 21 | 21,00 | 3,00 | 2,00 | | | |
| 22 | 22,00 | 3,00 | ,00 | | | |
| 23 | 23,00 | 3,00 | 3,00 | | | |
| 24 | 24,00 | 3,00 | 2,00 | | | |
| 25 | 25,00 | 3,00 | 1,00 | | | |
| 26 | 26,00 | 3,00 | 4,00 | | | |
| 27 | 27,00 | 3,00 | 2,00 | | | |
| 28 | 28,00 | 3,00 | 1,00 | | | |
| 29 | 29,00 | 3,00 | 3,00 | | | |
| 30 | 30,00 | 3,00 | 2,00 | | | |
| 31 | | | | | | |
| 32 | | | | | | |

# One-way univariate ANOVA



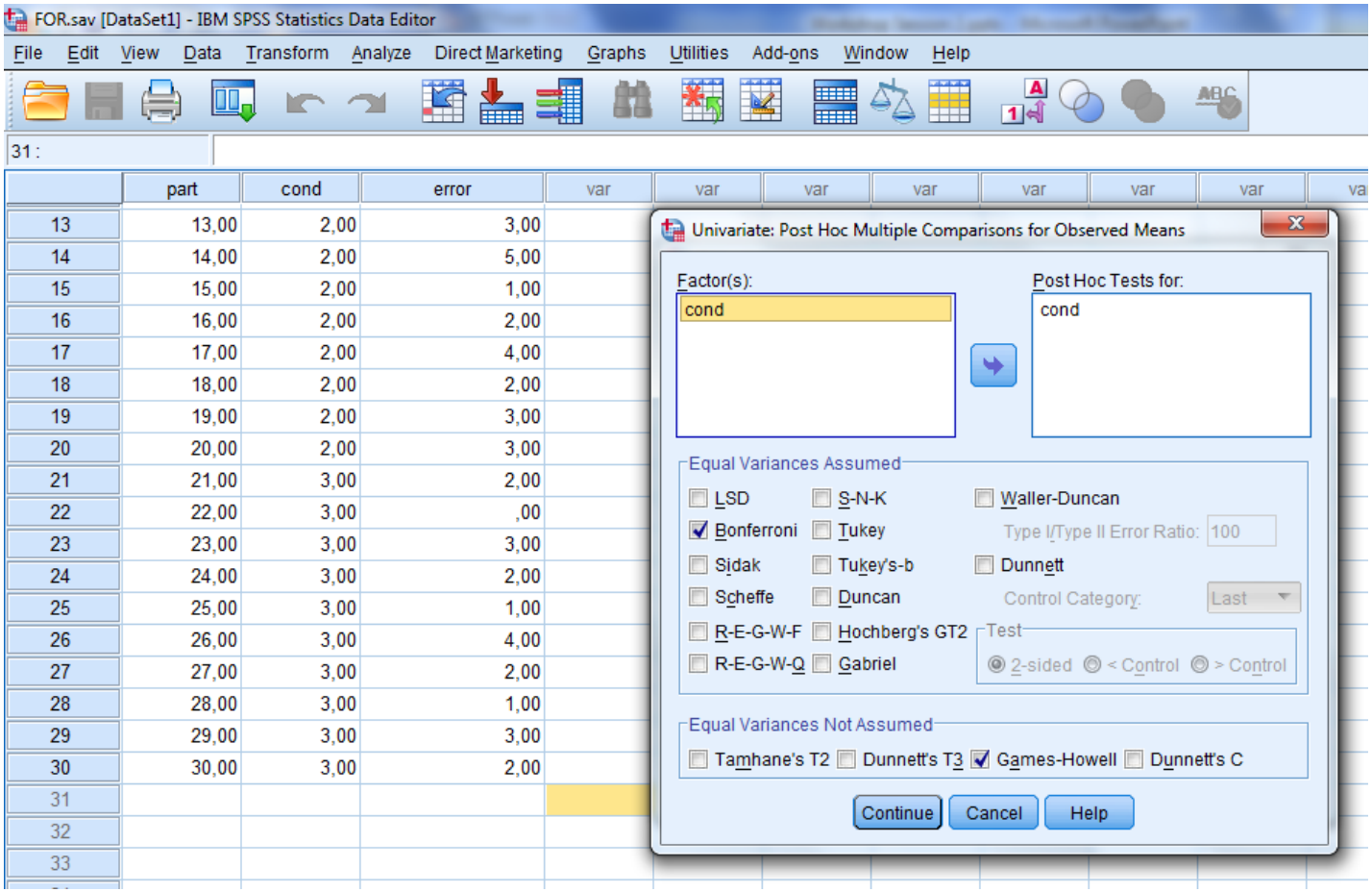

Analyze /
General Linear Model/
Univariate

# One-way univariate ANOVA



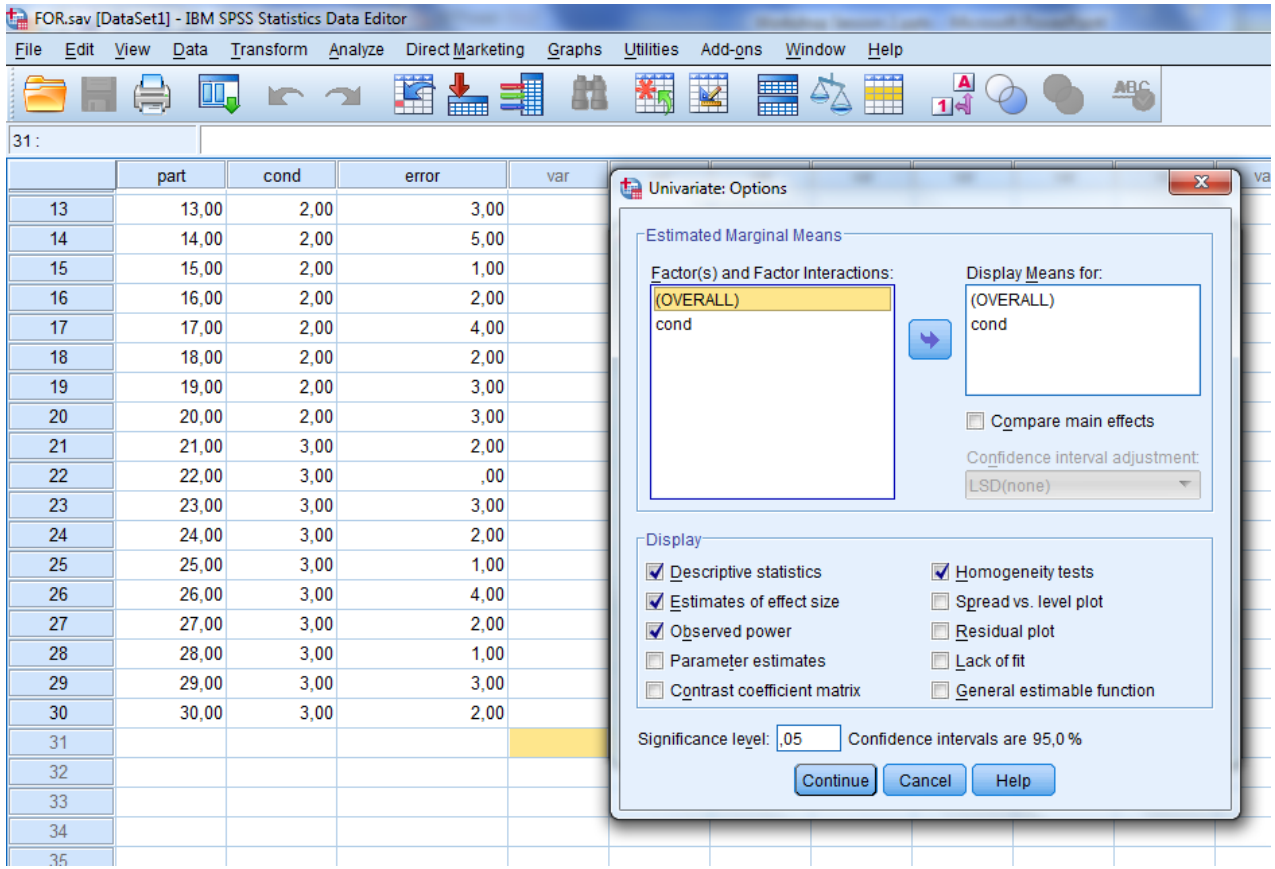

Determine DV and IV

# Post hoc Tests




Pick post hoc tests for differences between groups

# Options




| | part | cond | error | var |
|---|---|---|---|---|
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| 14 | 14,00 | 2,00 | 5,00 | |
| 15 | 15,00 | 2,00 | 1,00 | |
| 16 | 16,00 | 2,00 | 2,00 | |
| 17 | 17,00 | 2,00 | 4,00 | |
| 18 | 18,00 | 2,00 | 2,00 | |
| 19 | 19,00 | 2,00 | 3,00 | |
| 20 | 20,00 | 2,00 | 3,00 | |
| 21 | 21,00 | 3,00 | 2,00 | |
| 22 | 22,00 | 3,00 | ,00 | |
| 23 | 23,00 | 3,00 | 3,00 | |
| 24 | 24,00 | 3,00 | 2,00 | |
| 25 | 25,00 | 3,00 | 1,00 | |
| 26 | 26,00 | 3,00 | 4,00 | |
| 27 | 27,00 | 3,00 | 2,00 | |
| 28 | 28,00 | 3,00 | 1,00 | |
| 29 | 29,00 | 3,00 | 3,00 | |
| 30 | 30,00 | 3,00 | 2,00 | |
| 31 | | | | |
| 32 | | | | |
| 33 | | | | |
| 34 | | | | |
| 35 | | | | |

Display:
- descriptive statistics
- Estimates of effect size
- Observed power
- Homogeneity tests

# SPSS Output Descriptive Statistics

**Between-Subjects Factors**

| | | Value Label | N |
|---|---|---|---|
| condition | 1,00 | FOR 20 | 10 |
| | 2,00 | FOR 90 | 10 |
| | 3,00 | FOR 270 | 10 |

**Descriptive Statistics**

Dependent Variable: Number of errors

| condition | Mean | Std. Deviation | N |
|---|---|---|---|
| FOR 20 | 3,6000 | 1,34990 | 10 |
| FOR 90 | 2,9000 | 1,19722 | 10 |
| FOR 270 | 2,0000 | 1,15470 | 10 |
| Total | 2,8333 | 1,36668 | 30 |

# SPSS Output Homogeneity

Levene's Test of Equality of Error Variances[a]

Dependent Variable: Number of errors

| F | df1 | df2 | Sig. |
|---|---|---|---|
| ,945 | 2 | 27 | ,401 |

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + cond

Variances should be similar, therefore Levene‘s Test should show a non-significant result.

# SPSS Output Between-Subjects Effects

**Tests of Between-Subjects Effects**

Dependent Variable: Number of errors

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[b] |
|---|---|---|---|---|---|---|---|---|
| Corrected Model | 12,867[a] | 2 | 6,433 | 4,206 | ,026 | ,238 | 8,412 | ,689 |
| Intercept | 240,833 | 1 | 240,833 | 157,446 | ,000 | ,854 | 157,446 | 1,000 |
| cond | 12,867 | 2 | 6,433 | 4,206 | ,026 | ,238 | 8,412 | ,689 |
| Error | 41,300 | 27 | 1,530 | | | | | |
| Total | 295,000 | 30 | | | | | | |
| Corrected Total | 54,167 | 29 | | | | | | |

a. R Squared = ,238 (Adjusted R Squared = ,181)

b. Computed using alpha = ,05

# SPSS Output Post hoc Tests

**Multiple Comparisons**

Dependent Variable: Number of errors

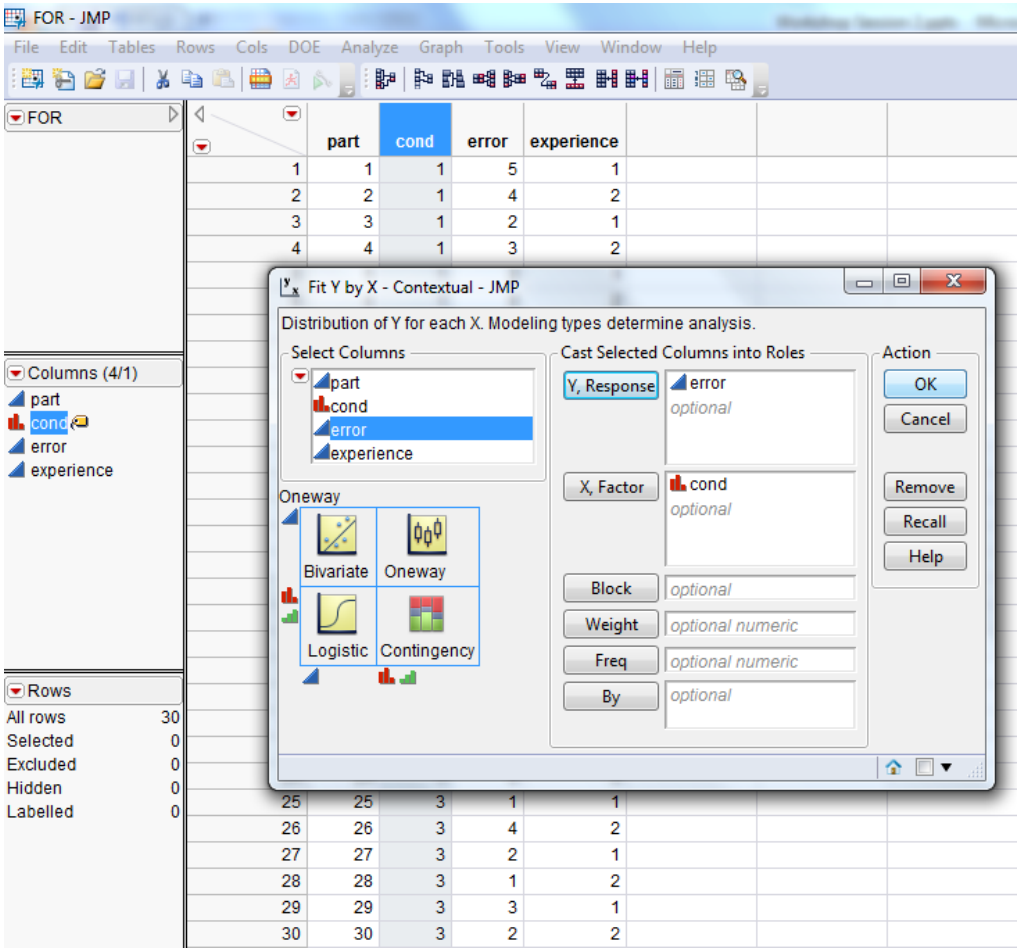
| | (I) condition | (J) condition | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Bonferroni | FOR 20 | FOR 90 | ,7000 | ,55311 | ,649 | -,7118 | 2,1118 |
| | | FOR 270 | 1,6000* | ,55311 | ,022 | ,1882 | 3,0118 |
| | FOR 90 | FOR 20 | -,7000 | ,55311 | ,649 | -2,1118 | ,7118 |
| | | FOR 270 | ,9000 | ,55311 | ,346 | -,5118 | 2,3118 |
| | FOR 270 | FOR 20 | -1,6000* | ,55311 | ,022 | -3,0118 | -,1882 |
| | | FOR 90 | -,9000 | ,55311 | ,346 | -2,3118 | ,5118 |
| Games-Howell | FOR 20 | FOR 90 | ,7000 | ,57057 | ,453 | -,7580 | 2,1580 |
| | | FOR 270 | 1,6000* | ,56174 | ,028 | ,1633 | 3,0367 |
| | FOR 90 | FOR 20 | -,7000 | ,57057 | ,453 | -2,1580 | ,7580 |
| | | FOR 270 | ,9000 | ,52599 | ,228 | -,4426 | 2,2426 |
| | FOR 270 | FOR 20 | -1,6000* | ,56174 | ,028 | -3,0367 | -,1633 |
| | | FOR 90 | -,9000 | ,52599 | ,228 | -2,2426 | ,4426 |

Based on observed means.

The error term is Mean Square(Error) = 1,530.

*. The mean difference is significant at the ,05 level.

# Output JMP


FOR - JMP
File Edit Tables Rows Cols DOE Analyze Graph Tools View Window Help
FOR
part cond error experience
1 1 1 5 1
2 2 1 4 2
3 3 1 2 1
4 4 1 3 2
Columns (4/1)
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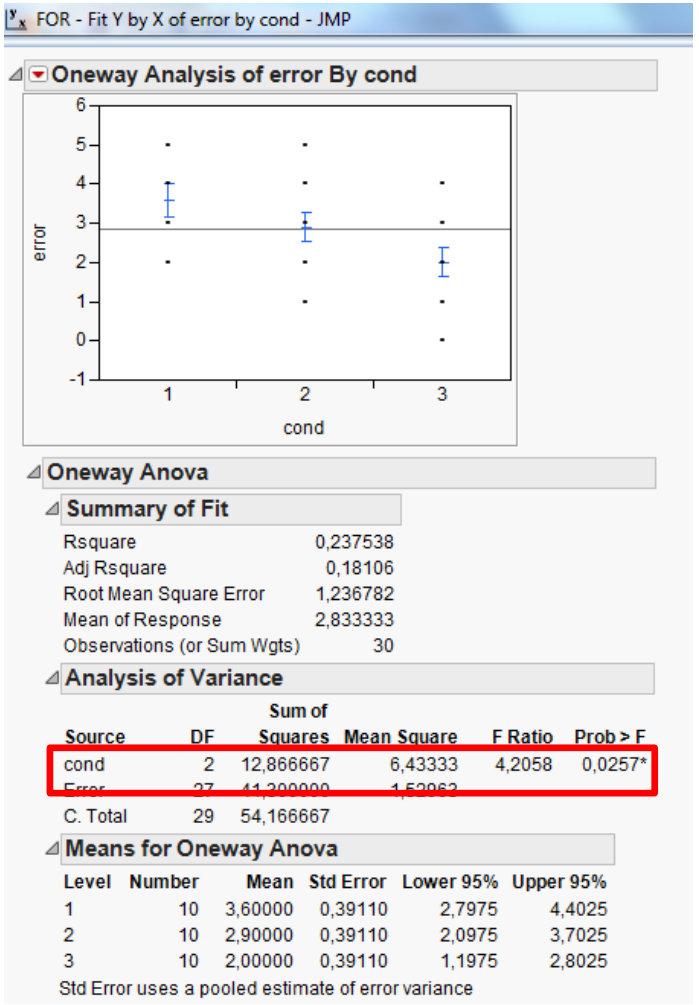
cond
error
experience
Rows
All rows 30
Selected 0
Excluded 0
Hidden 0
Labelled 0
Fit Y by X - Contextual - JMP
Distribution of Y for each X. Modeling types determine analysis.
Select Columns
part
cond
error
experience
Cast Selected Columns into Roles
Y, Response
error
optional
X, Factor
cond
optional
Block
optional
Weight
optional numeric
Freq
optional numeric
By
optional
Action
OK
Cancel
Remove
Recall
Help
Oneway
Bivariate
Oneway
Logistic
Contingency
25 25 3 1 1
26 26 3 4 2
27 27 3 2 1
28 28 3 1 2
29 29 3 3 1
30 30 3 2 2


FOR - Fit Y by X of error by cond - JMP
Oneway Analysis of error By cond
error
cond
Oneway Anova
Summary of Fit
Rsquare 0,237538
Adj Rsquare 0,18106
Root Mean Square Error 1,236782
Mean of Response 2,833333
Observations (or Sum Wgts) 30
Analysis of Variance
Source DF Sum of Squares Mean Square F Ratio Prob > F
cond 2 12,866667 6,43333 4,2058 0,0257*
Error 27 41,300000 1,52963
C. Total 29 54,166667
Means for Oneway Anova
Level Number Mean Std Error Lower 95% Upper 95%
1 10 3,60000 0,39110 2,7975 4,4025
2 10 2,90000 0,39110 2,0975 3,7025
3 10 2,00000 0,39110 1,1975 2,8025
Std Error uses a pooled estimate of error variance

# Results

- H1: Higher field of regard leads to reduced error rate in a search task.
- $M_{FOR20} = 3.60$ (SD = 1.35; n = 10)
- $M_{FOR90} = 2.90$ (SD = 1.20; n = 10)
- $M_{FOR270} = 2.00$ (SD = 1.15; n = 10)
- Partial $\eta^2 = .24$ (large)
- $F = 4.21$; $df = 2$; $p = .026$
- $\rightarrow H_0$ is rejected for FOR20 and FOR270

# MULTI-FACTORIAL, REPEATED MEASURES

# Multi-factorial ANOVA

- Multi-factorial,
  - At least 2 IV, at least 1 DV
  - Cross-sectional or repeated measures
  - Interaction effects

| | No sound | Spatial Sound |
|---|---|---|
| No sound first | | |
| Sound first | | |

IV 1: sound (no sound / spatial sound)
IV 2: order of presentation (no sound first / spatial sound first)
DV: presence experienced (SUS Mean)

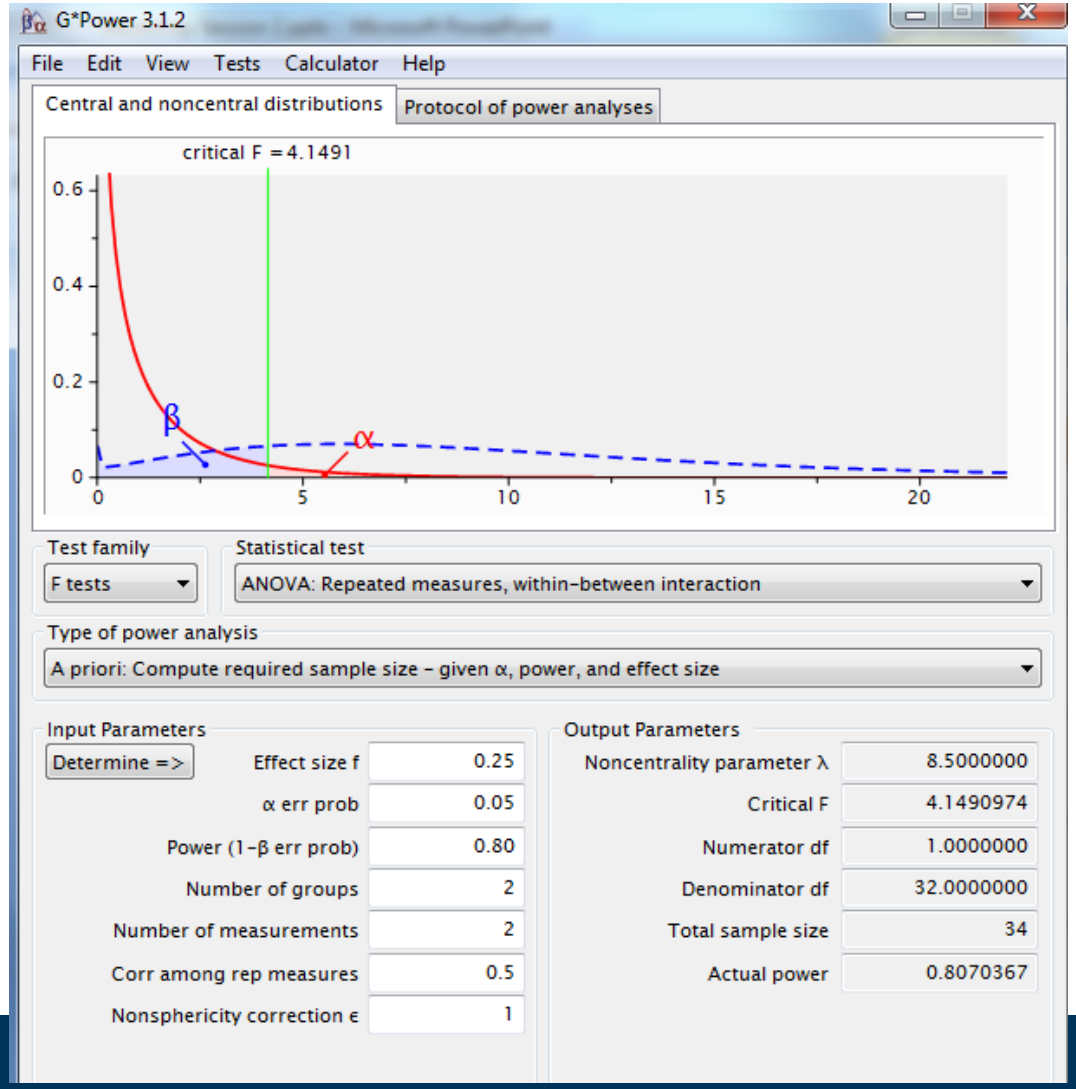
# Which test?

- H1: Integrating spatial sound into a VR scene leads to higher levels of presence experienced than a no sound display.
- Hypothesis on a difference
- 1 within-subjects factor (sound), 1 between-subjects factor (order of presentation)
- 1 dependent variable (presence experienced, interval)
- → Two-way ANOVA, repeated measures

# Requirements ANOVA, Repeated Measurements

- DV = interval / ratio, normal distribution
- Complete dataset per participant for several measurements (conditions, points in time)
- Covariances between different measurements have to be similar (sphericity)
- Non-parametrical alternative: Friedman-Test

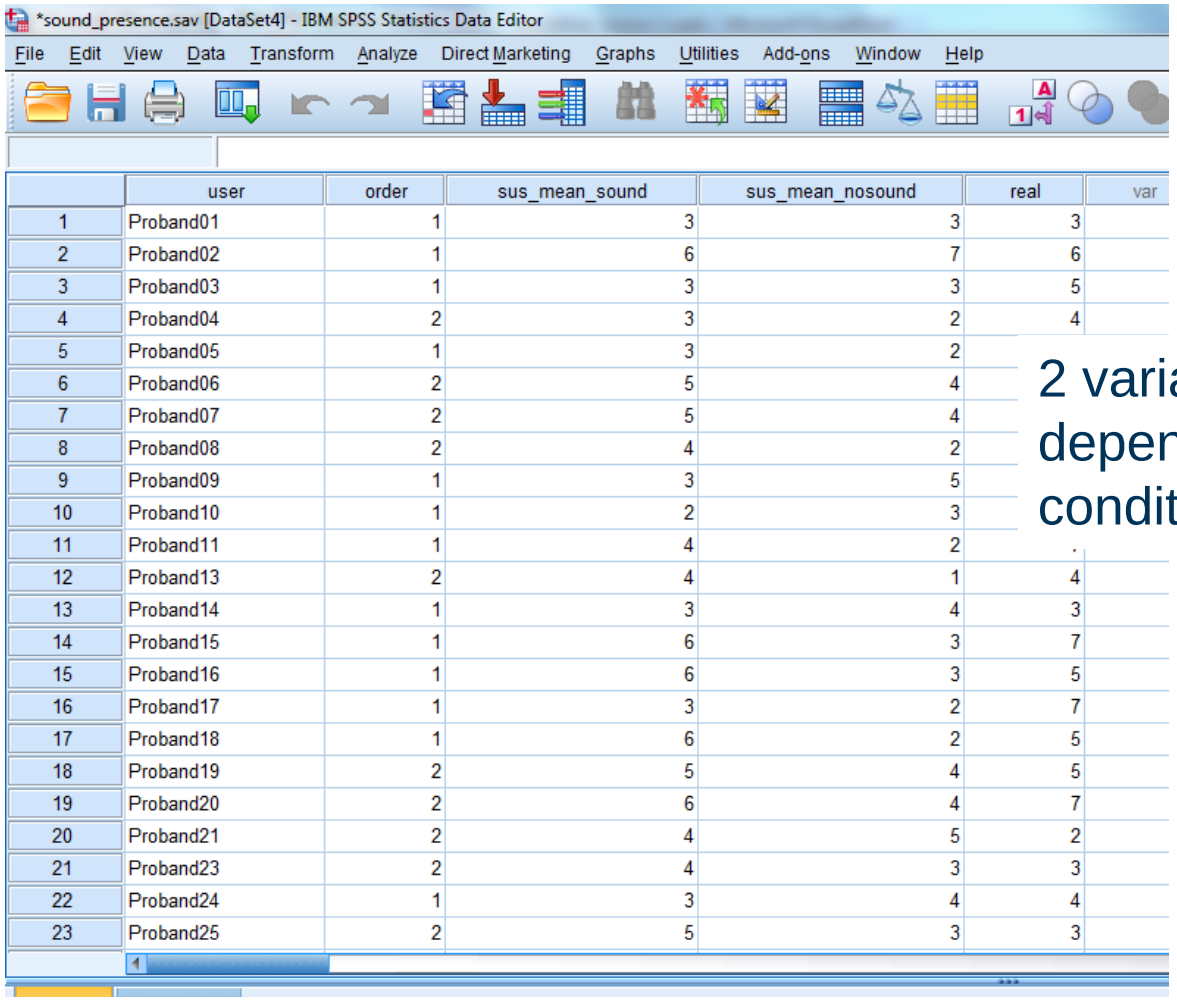
# A priori power analysis




- Test family: F tests
- Statistical test: ANOVA, repeated measures, within-between interaction
- Type of power analysis: A priori
- Medium effect size f=.25
- α = .05
- 1-β = .80
- Number of groups = 2
- Number of measurements = 2

- Total sample size = 34

# Data Set

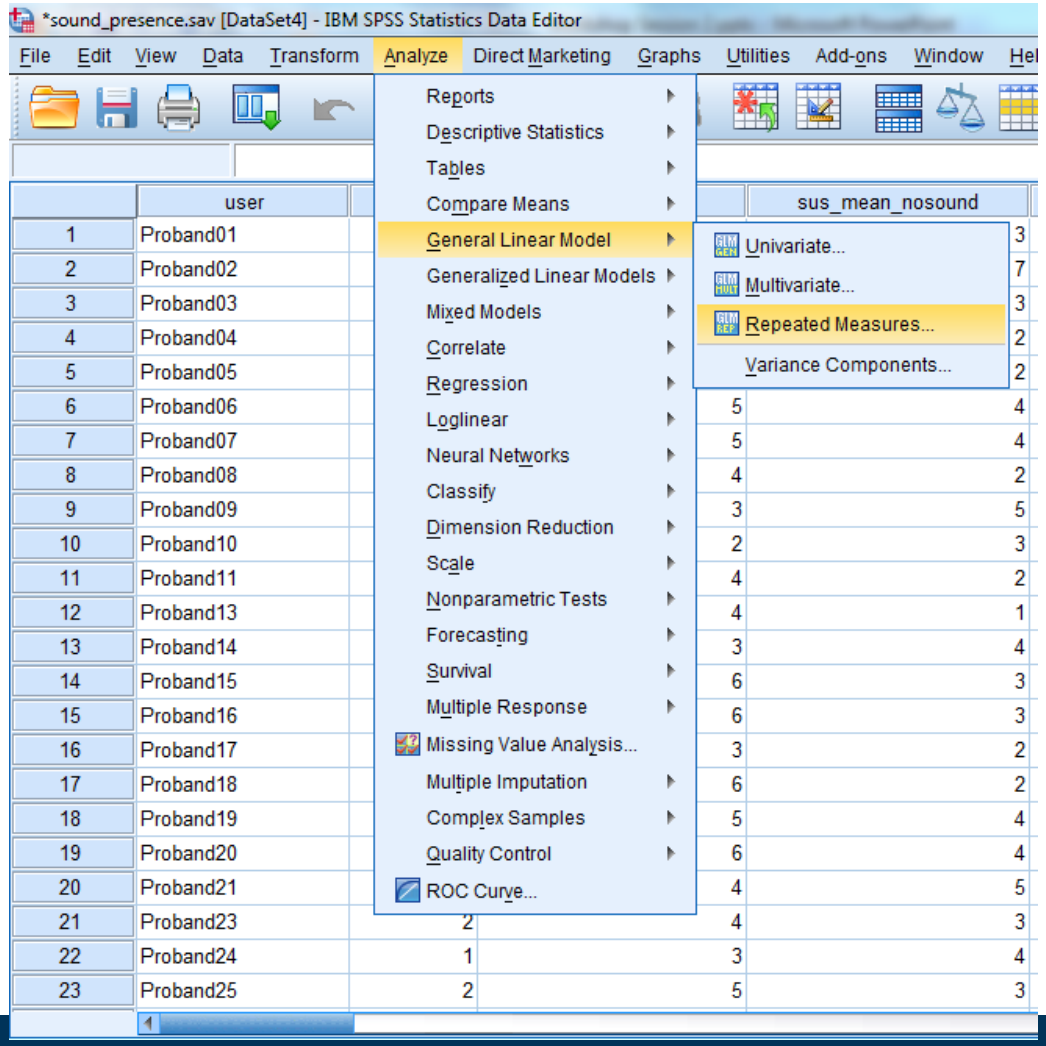

*sound_presence.sav [DataSet4] - IBM SPSS Statistics Data Editor

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

| | user | order | sus_mean_sound | sus_mean_nosound | real | var |
|---|---|---|---|---|---|---|
| 1 | Proband01 | 1 | 3 | 3 | 3 | |
| 2 | Proband02 | 1 | 6 | 7 | 6 | |
| 3 | Proband03 | 1 | 3 | 3 | 5 | |
| 4 | Proband04 | 2 | 3 | 2 | 4 | |
| 5 | Proband05 | 1 | 3 | 2 | | |
| 6 | Proband06 | 2 | 5 | 4 | | |
| 7 | Proband07 | 2 | 5 | 4 | | |
| 8 | Proband08 | 2 | 4 | 2 | | |
| 9 | Proband09 | 1 | 3 | 5 | | |
| 10 | Proband10 | 1 | 2 | 3 | | |
| 11 | Proband11 | 1 | 4 | 2 | | |
| 12 | Proband13 | 2 | 4 | 1 | 4 | |
| 13 | Proband14 | 1 | 3 | 4 | 3 | |
| 14 | Proband15 | 1 | 6 | 3 | 7 | |
| 15 | Proband16 | 1 | 6 | 3 | 5 | |
| 16 | Proband17 | 1 | 3 | 2 | 7 | |
| 17 | Proband18 | 1 | 6 | 2 | 5 | |
| 18 | Proband19 | 2 | 5 | 4 | 5 | |
| 19 | Proband20 | 2 | 6 | 4 | 7 | |
| 20 | Proband21 | 2 | 4 | 5 | 2 | |
| 21 | Proband23 | 2 | 4 | 3 | 3 | |
| 22 | Proband24 | 1 | 3 | 4 | 4 | |
| 23 | Proband25 | 2 | 5 | 3 | 3 | |

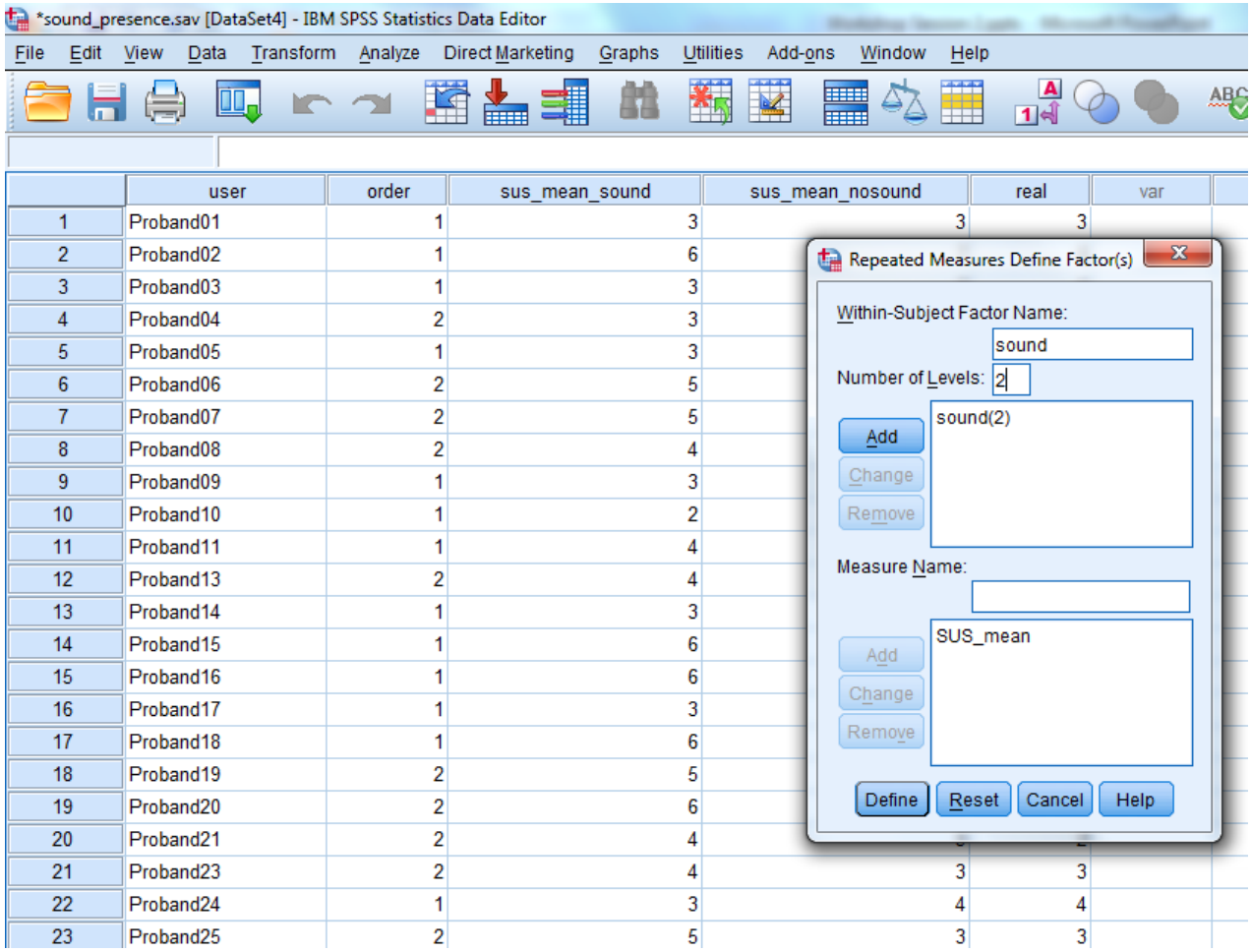
2 variables / participant: dependent variable for condition 1 and condition 2

# Two-way ANOVA, repeated measures




Analyze / General Linear Model / Repeated Measures

# Two-way ANOVA, repeated measures



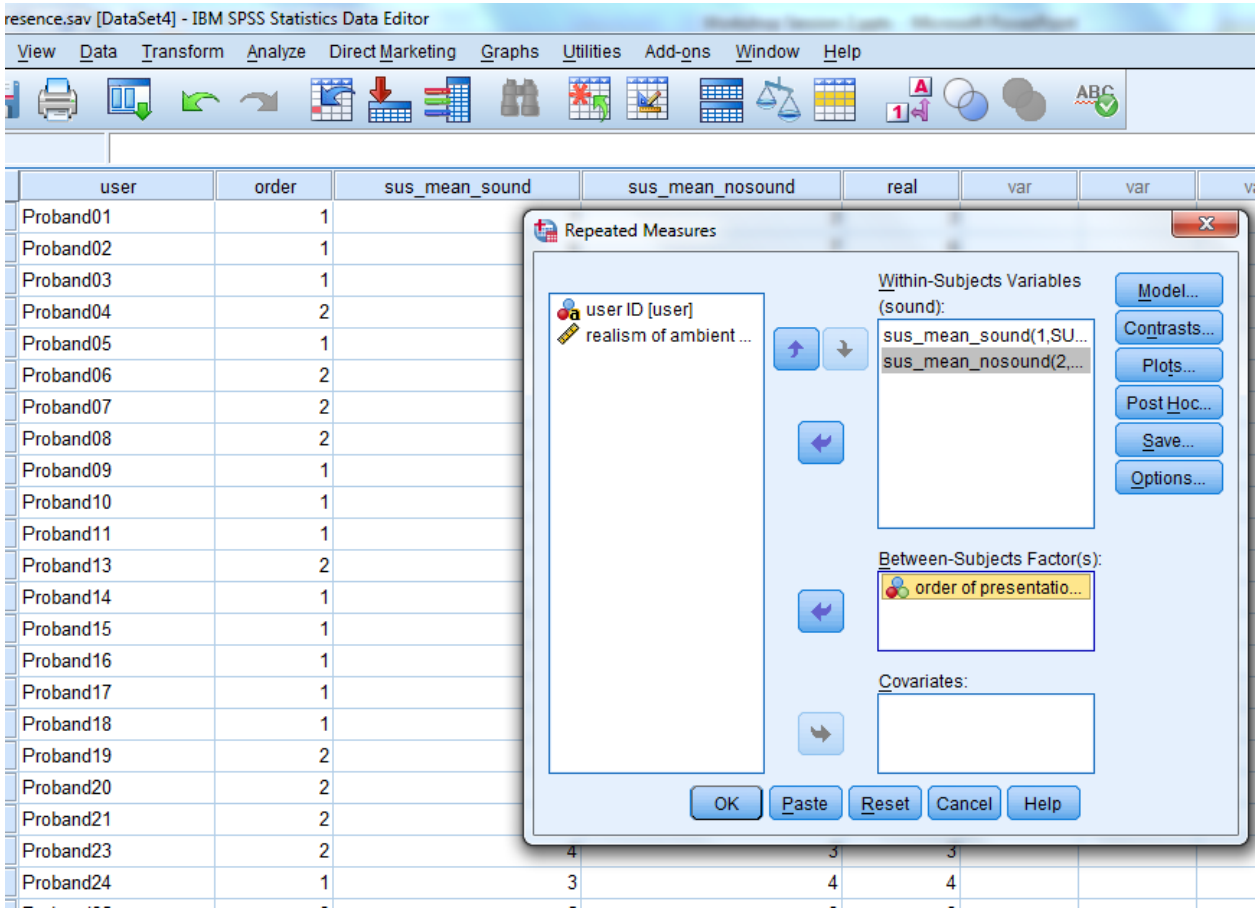

| | user | order | sus_mean_sound | sus_mean_nosound | real | var |
|---|---|---|---|---|---|---|
| 1 | Proband01 | 1 | 3 | 3 | 3 | |
| 2 | Proband02 | 1 | 6 | | | |
| 3 | Proband03 | 1 | 3 | | | |
| 4 | Proband04 | 2 | 3 | | | |
| 5 | Proband05 | 1 | 3 | | | |
| 6 | Proband06 | 2 | 5 | | | |
| 7 | Proband07 | 2 | 5 | | | |
| 8 | Proband08 | 2 | 4 | | | |
| 9 | Proband09 | 1 | 3 | | | |
| 10 | Proband10 | 1 | 2 | | | |
| 11 | Proband11 | 1 | 4 | | | |
| 12 | Proband13 | 2 | 4 | | | |
| 13 | Proband14 | 1 | 3 | | | |
| 14 | Proband15 | 1 | 6 | | | |
| 15 | Proband16 | 1 | 6 | | | |
| 16 | Proband17 | 1 | 3 | | | |
| 17 | Proband18 | 1 | 6 | | | |
| 18 | Proband19 | 2 | 5 | | | |
| 19 | Proband20 | 2 | 6 | | | |
| 20 | Proband21 | 2 | 4 | | | |
| 21 | Proband23 | 2 | 4 | 3 | 3 | |
| 22 | Proband24 | 1 | 3 | 4 | 4 | |
| 23 | Proband25 | 2 | 5 | 3 | 3 | |



Determine within-subjects factor (sound) and number of levels

Determine DV (measure name)

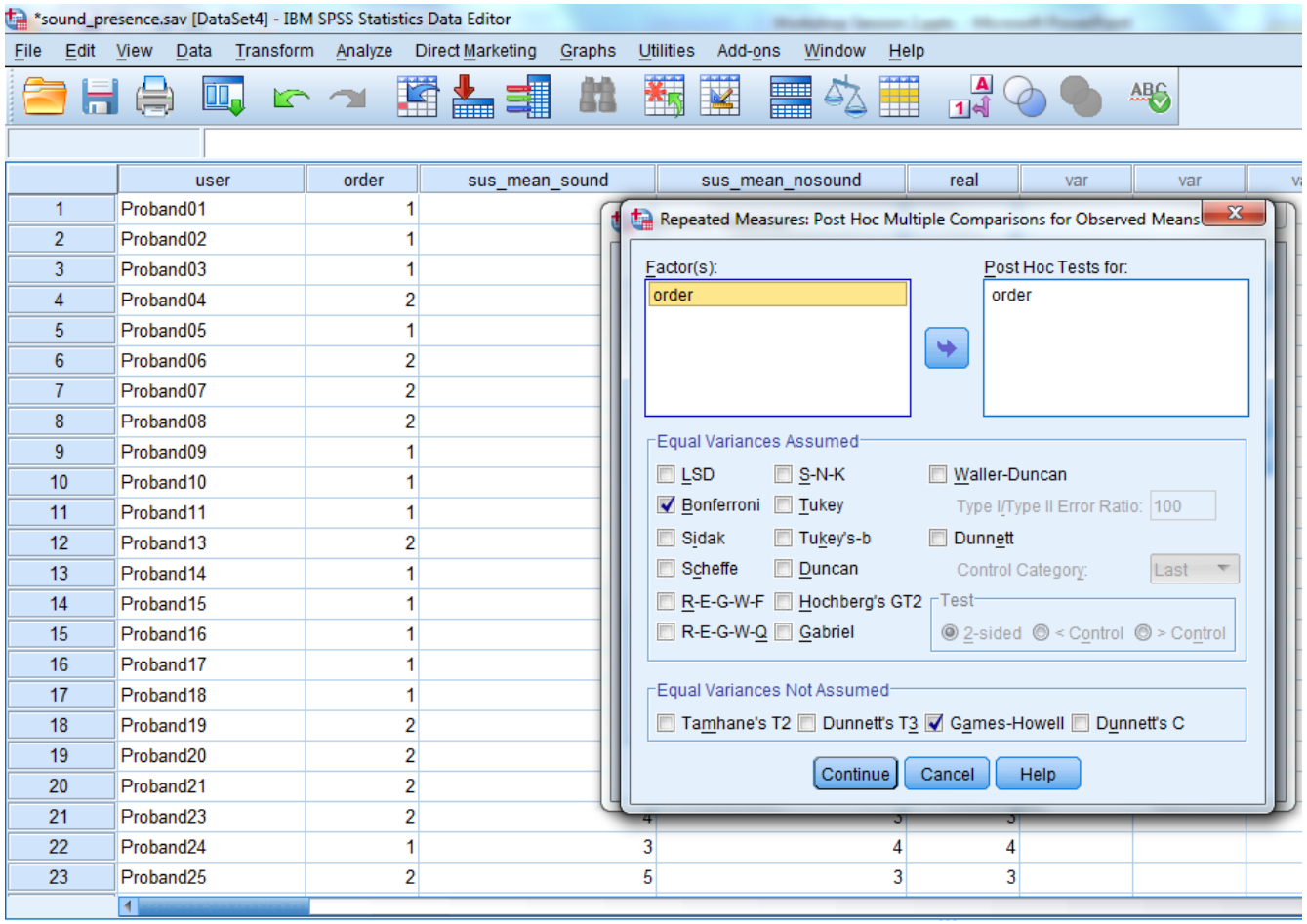
# Two-way ANOVA, repeated measures




Add DV to analysis (NB: 2 variables!)

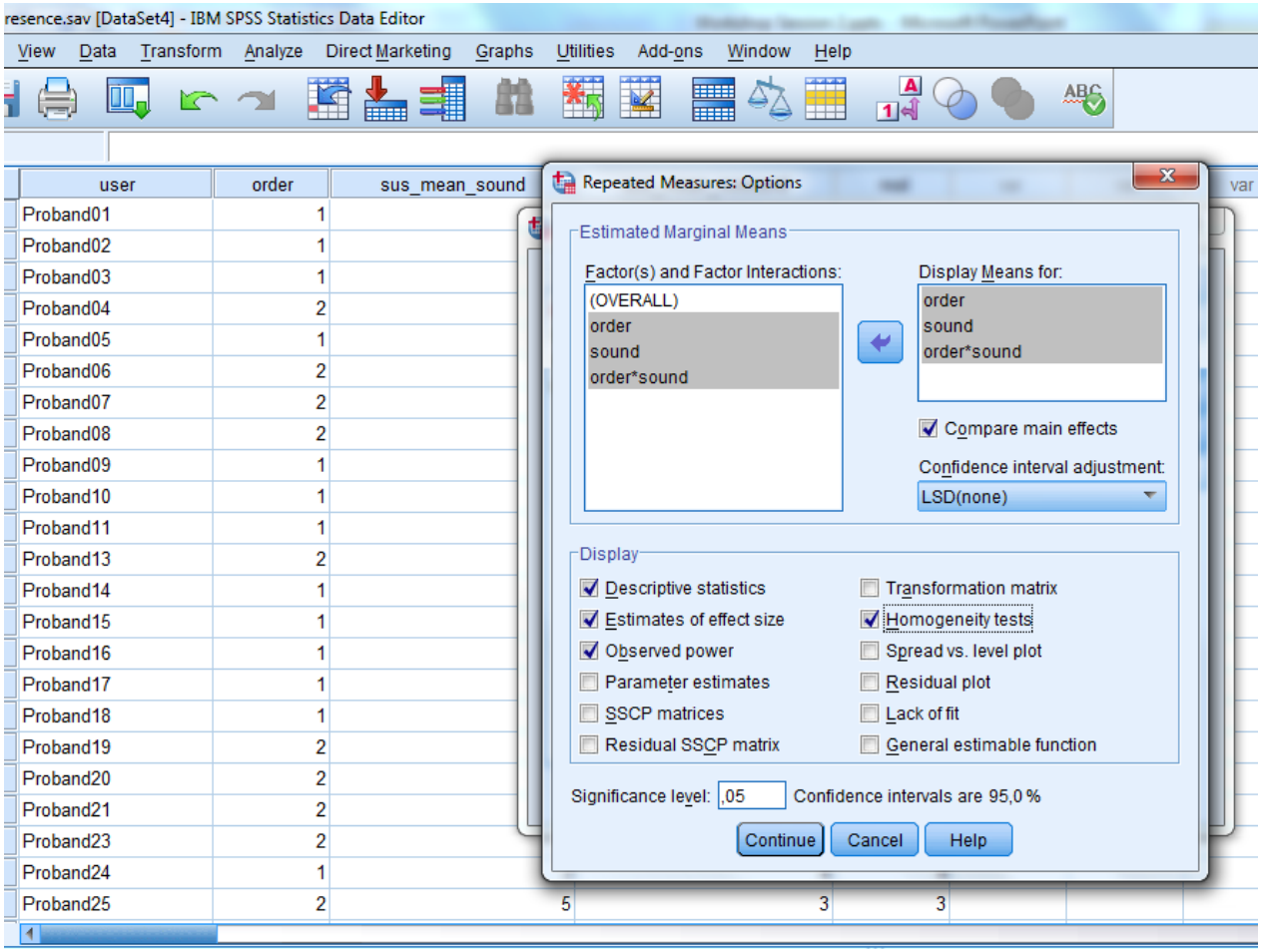
Determine between-subjects factor (order of presentation

# Two-way ANOVA, repeated measures




Check post hoc tests

# Two-way ANOVA, repeated measures




Display:
- descriptive statistics for factors and interaction
- Estimates of effect size
- Observed power
- Homogeneity tests

# SPSS Output - Factors

**Within-Subjects Factors**

Measure: SUS_mean

| sound | Dependent Variable |
|---|---|
| 1 | sus_mean_sound |
| 2 | sus_mean_nosound |

**Between-Subjects Factors**

| | | Value Label | N |
|---|---|---|---|
| order of presentation | 1 | sound first | 33 |
| | 2 | no sound first | 33 |

# SPSS Output – Descriptive Statistics

**Descriptive Statistics**

| | order of presentation | Mean | Std. Deviation | N |
|---|---|---|---|---|
| SUS Mean sound | sound first | 3,70 | 1,163 | 33 |
| | no sound first | 4,68 | 1,219 | 33 |
| | Total | 4,19 | 1,282 | 66 |
| SUS Mean no sound | sound first | 2,76 | 1,289 | 33 |
| | no sound first | 3,55 | 1,326 | 33 |
| | Total | 3,15 | 1,358 | 66 |

# SPSS Output – Levene‘s Test

**Levene's Test of Equality of Error Variances[a]**

| | F | df1 | df2 | Sig. |
|---|---|---|---|---|
| SUS Mean sound | ,054 | 1 | 64 | ,817 |
| SUS Mean no sound | ,259 | 1 | 64 | ,613 |

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + order
Within Subjects Design: sound

Variances should be similar, therefore Levene‘s Test should show a non-significant result.

# SPSS Output - Sphericity

**Mauchly's Test of Sphericity[b]**

Measure: SUS_mean

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon[a] | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| sound | 1,000 | ,000 | 0 | . | 1,000 | 1,000 | 1,000 |

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b. Design: Intercept + order

Within Subjects Design: sound

# SPSS Output within-subjects effects

**Tests of Within-Subjects Effects**

Measure: SUS_mean

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[a] |
|---|---|---|---|---|---|---|---|---|---|
| sound | Sphericity Assumed | 35,375 | 1 | 35,375 | 55,123 | ,000 | ,463 | 55,123 | 1,000 |
| | Greenhouse-Geisser | 35,375 | 1,000 | 35,375 | 55,123 | ,000 | ,463 | 55,123 | 1,000 |
| | Huynh-Feldt | 35,375 | 1,000 | 35,375 | 55,123 | ,000 | ,463 | 55,123 | 1,000 |
| | Lower-bound | 35,375 | 1,000 | 35,375 | 55,123 | ,000 | ,463 | 55,123 | 1,000 |
| sound * order | Sphericity Assumed | ,304 | 1 | ,304 | ,474 | ,494 | ,007 | ,474 | ,104 |
| | Greenhouse-Geisser | ,304 | 1,000 | ,304 | ,474 | ,494 | ,007 | ,474 | ,104 |
| | Huynh-Feldt | ,304 | 1,000 | ,304 | ,474 | ,494 | ,007 | ,474 | ,104 |
| | Lower-bound | ,304 | 1,000 | ,304 | ,474 | ,494 | ,007 | ,474 | ,104 |
| Error(sound) | Sphericity Assumed | 41,072 | 64 | ,642 | | | | | |
| | Greenhouse-Geisser | 41,072 | 64,000 | ,642 | | | | | |
| | Huynh-Feldt | 41,072 | 64,000 | ,642 | | | | | |
| | Lower-bound | 41,072 | 64,000 | ,642 | | | | | |

a. Computed using alpha = ,05

# SPSS Output – Between-Subjects Effects

**Tests of Between-Subjects Effects**

Measure: SUS_mean
Transformed Variable: Average

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared | Noncent. Parameter | Observed Power[a] |
|---|---|---|---|---|---|---|---|---|
| Intercept | 1779,559 | 1 | 1779,559 | 715,524 | ,000 | ,918 | 715,524 | 1,000 |
| order | 26,074 | 1 | 26,074 | 10,484 | ,002 | ,141 | 10,484 | ,890 |
| Error | 159,173 | 64 | 2,487 | | | | | |

a. Computed using alpha = ,05

# Results

- H1: Integrating spatial sound into a VR scene leads to higher levels of presence experienced than a no sound display.
- $M_{\text{no sound}} = 3.15$ (SD = 1.36; n = 66)
- $M_{\text{sound}} = 4.19$ (SD = 1.28; n = 66)
- Partial $\eta^2 = .46$ (large)
- $F = 55.12$; $df = 1$; $p = .002$
- $\rightarrow H_0$ is rejected

# Further Reading


- Field, A. (2013). *Discovering Statistics Using IBM SPSS Statistics*.(4th ed.).Thousand Oaks: Sage Publications
- Howell, D. (2012). *Statistical Methods for Psychology*. (8th ed.). Cengage Learning Emea
- Marques de Sá, J. P. (2007). *Applied Statistics Using SPSS, STATISTICA, MATLAB and R*. (2nd ed.) Berlin: Springer.