Analysis of Variance (PC exercise)

Sebastian Jentschke

Agenda

- Preparing your data
- ANOVA – Use in SPSS
  - t-test to one-factorial ANOVA
  - ANCOVA
  - MANOVA
  - Repeated-measures ANOVA – Profile analysis
- ANOVA – Assignment

Acquire and organize a data set...

- Choose a code build up according to a schema, e.g., EXP_SUBJNR_DATE
- ideally 2 complementary parts (SUBJNR – DATE)
- create a unique directory structure; either SUBJ – measures or MEASURE – subjects
- try to computerize as many tasks as possible (convenience and smaller risk for errors)

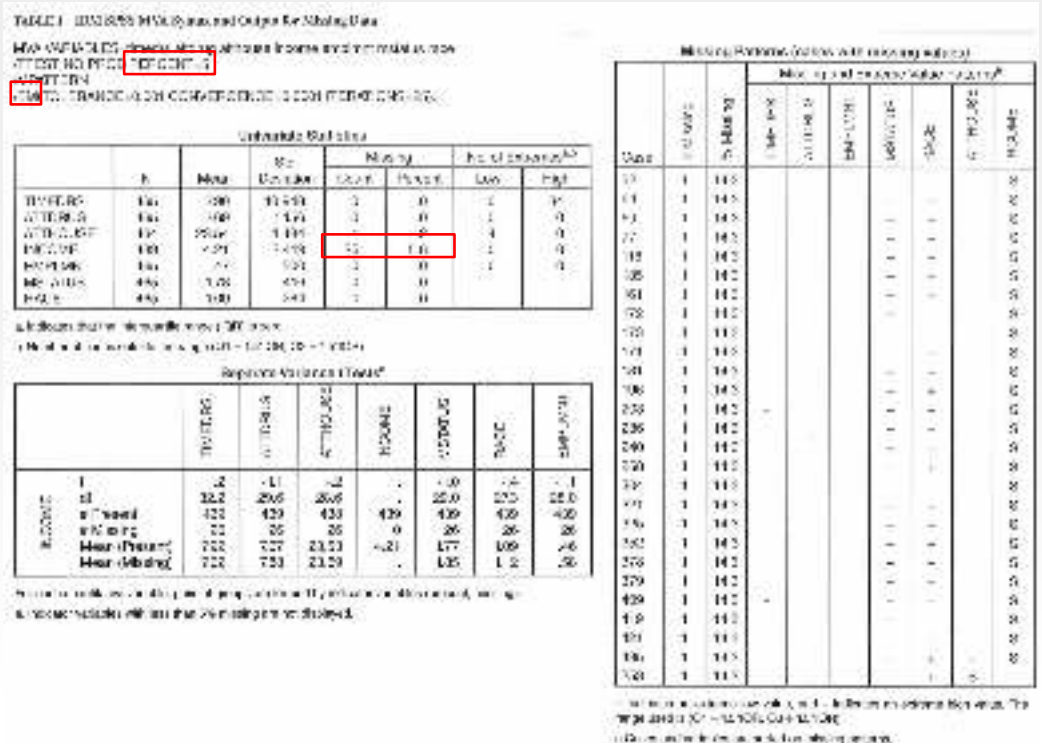
Acquire and organize a data set...

- describe / label your variables:
  - in SPSS: use clear and descriptive labels
  - for R: describe the coding (e.g., 1 = male, 2 = female) in a comment in the syntax
- allow yourself (and others) to understand your analyses) – data repositories
  - store syntax files
  - make an description of the variables / files in the study in the main directory

Before you start analysing

- screening for obviously invalid data (e.g., response set: always the same response)
  EXCEL: COUNTIF, STDEV
- how to deal with invalid / missing data
  Analyze → Missing value analysis
  - threshold for acceptable missing data?
  - exclude variables or cases?
  - replacement / computation?
- calculating sum scores or latent variables

Before you start analysing

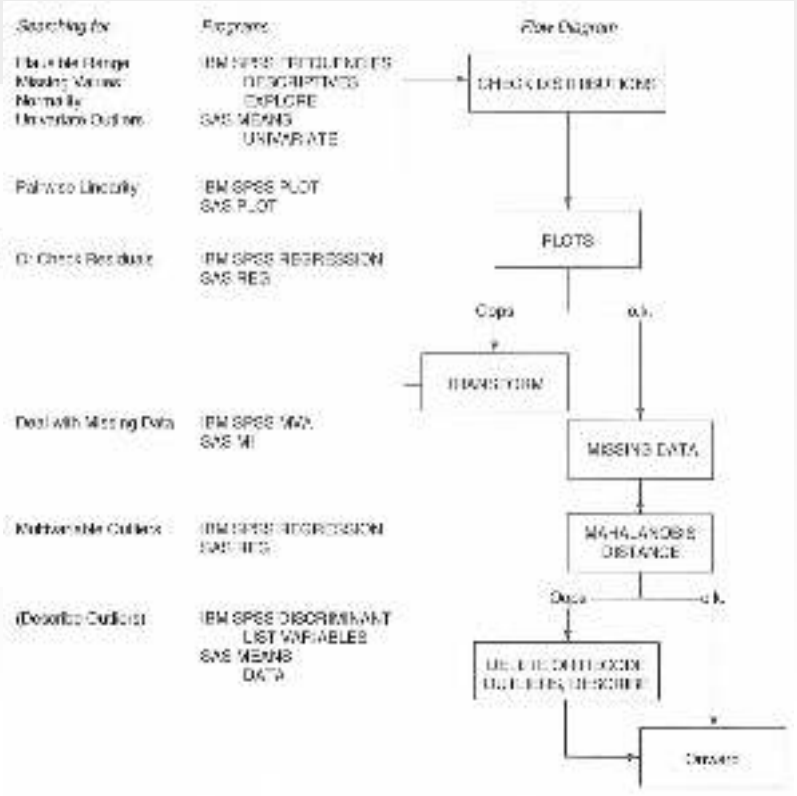


EM performs an expectation-maximization-estimation for missing values; if OUTFILE is given, these EM-estimated variables are saved alternatively, /REGRESSION can be used for a regression-based-estimation

Questions?
Comments?

Parametric vs. non-parametric

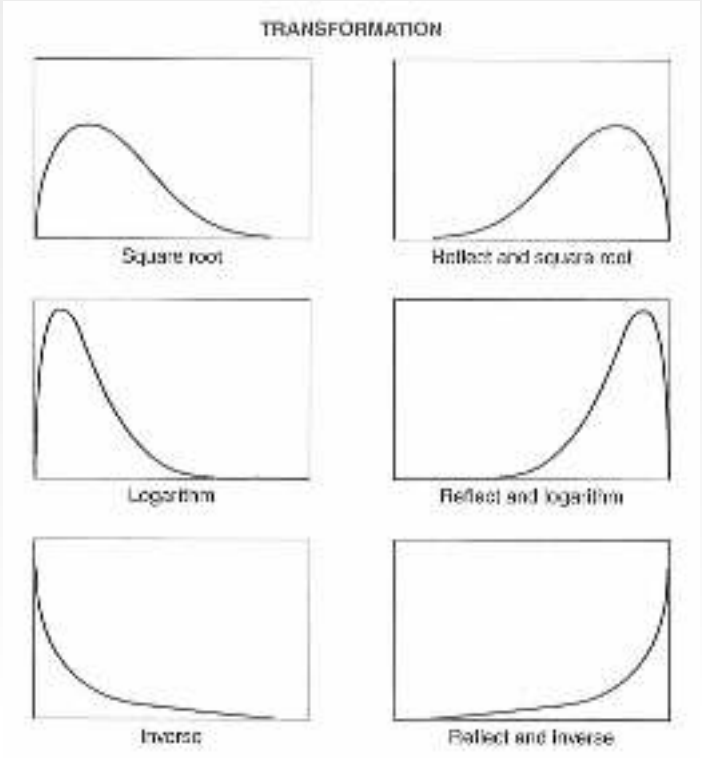
1. Inspect univariate descriptive statistics for accuracy of input
   a. Out-of-range values
   b. Plausible means and standard deviations
   c. Univariate outliers
2. Evaluate amount and distribution of missing data; deal with problem
3. Check pairwise plots for nonlinearity and heteroscedasticity
4. Identify and deal with nonnormal variables and univariate outliers
   a. Check skewness and kurtosis, probability plots
   b. Transform variables (if desirable)
   c. Check results of transformation
5. Identify and deal with multivariate outliers
   a. Variables causing multivariate outliers
   b. Description of multivariate outliers
6. Evaluate variables for multicollinearity and singularity



Checking for outliers

- univariate – SPSS FREQUENCIES (box plots; for N < 1000 → p = .001 → z = ±3.3; only for DV and IVs that are used as covariates)
- multivariate: SPSS REGRESSION (Save → Distances → Mahalanobis; calculate “SIG.CHISQ(MAH_1,3)” and exclude p < .001; only for DV and IVs as covariates)
- IQR = Q3 – Q1 (sort your variable, take 25% position [Q1] and 75% position [Q3])
  Outlier: Q1 – IQR * 1.5 [liberal] / 3.0 [strict]
  Q3 + IQR * 1.5 [liberal] / 3.0 [strict]

Data transformations



Moderate positive skewness	NEWX=SQRT(X)
Substantial positive skewness	NEWX=LG10(X)
With zero	NEWX=LG10(X + C)
Severe positive skewness	NEWX=1/X
J-shaped With zero	NEWX=1/(X + C)
Moderate negative skewness	NEWX=SQRT(K − X)
Substantial negative skewness	NEWX=LG10(K − X)
Severe negative skewness J-shaped	NEWX=1/(K − X)

C = a constant added to each score so that the smallest score is 1;

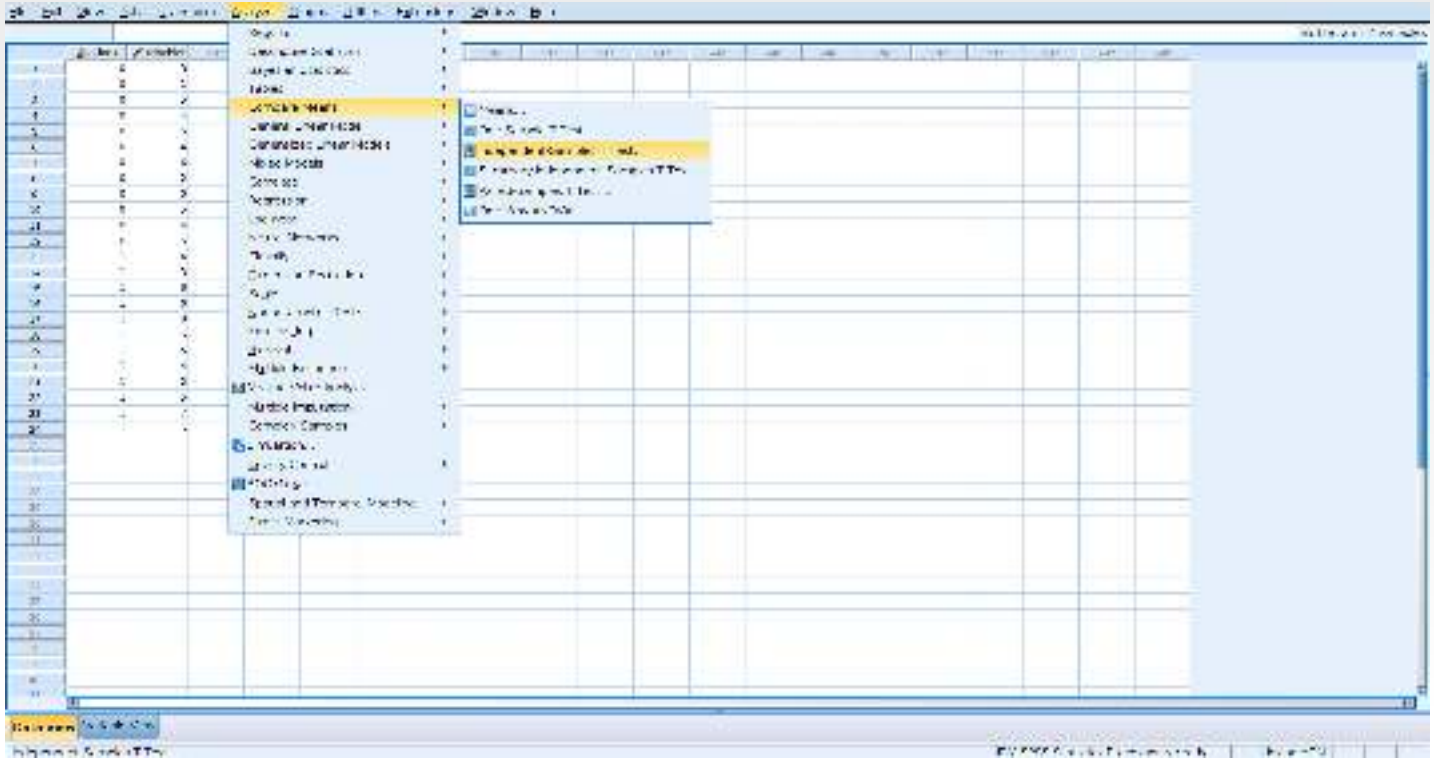
K = a constant from which each score is subtracted so that the smallest score is 1; usually equal to the largest score + 1

Questions?
Comments?

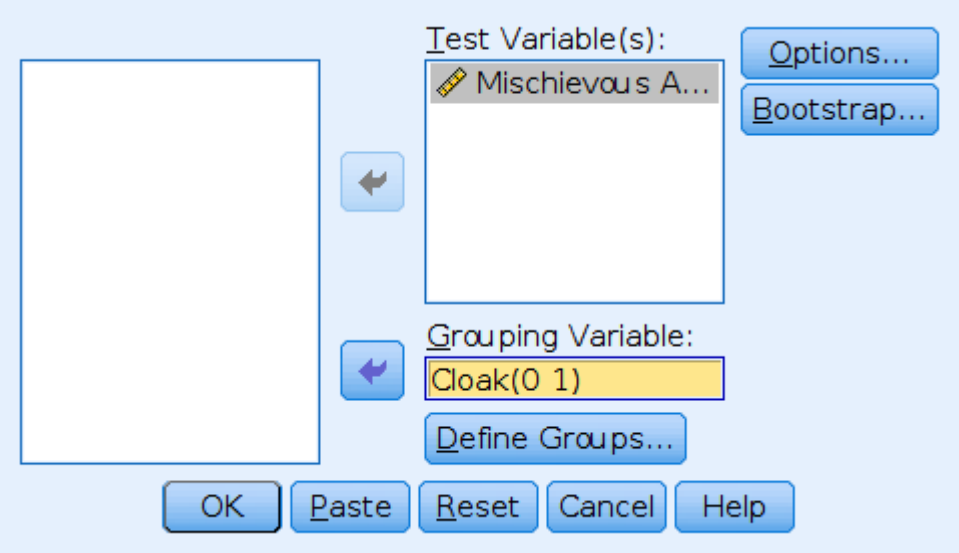
From t-test to ANOVA

- ***Invisibility.sav*** from Fields data set
  1 predictor (two step) – 1 dependent variable:
  → Analyze → Descriptive Statistics → Explore
  (switch on Boxplots and Normality plots under Plots)
  → Analyze → Compare Means → t-test for independent samples
  (check for Homogeneity of Variance and choose results accordingly)
  → Analyze → General Linear Model → Univariate...

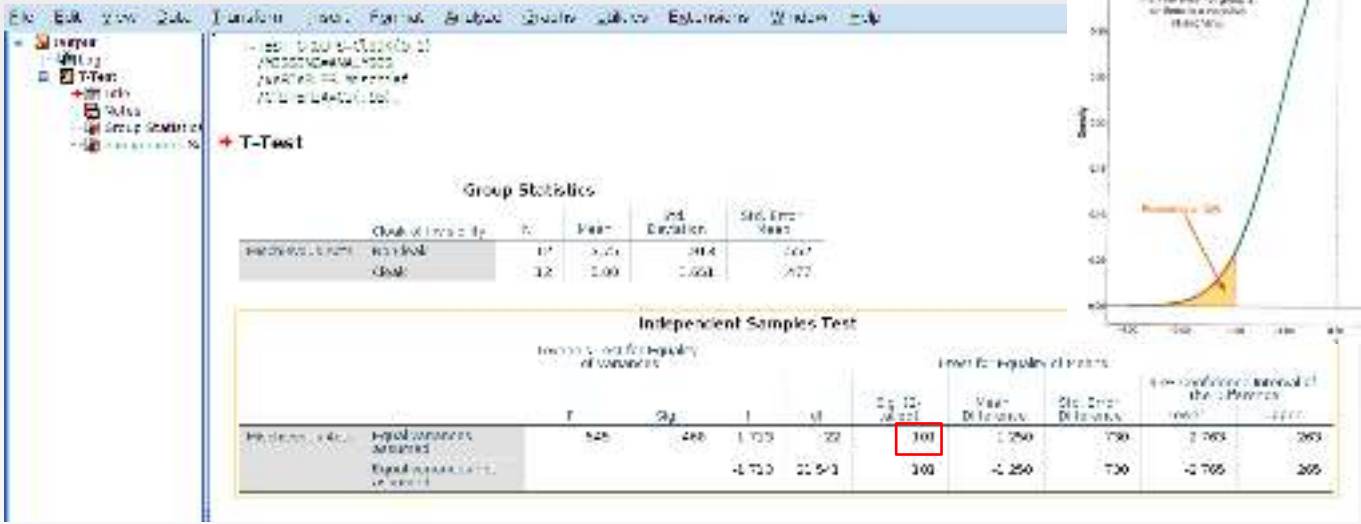
From t-test to ANOVA

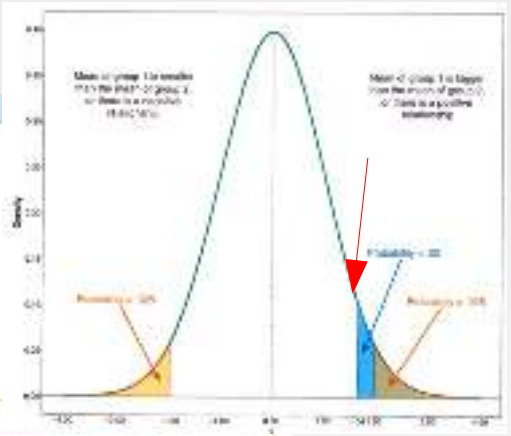


From t-test to ANOVA

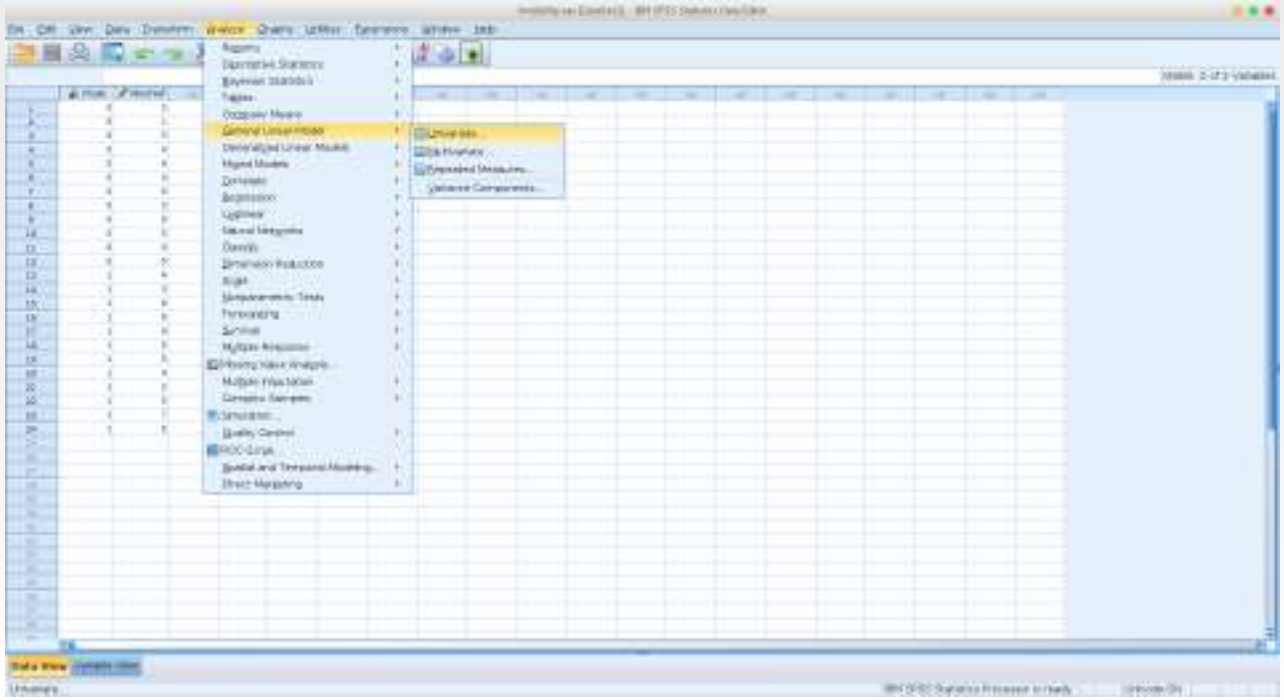


From t-test to ANOVA

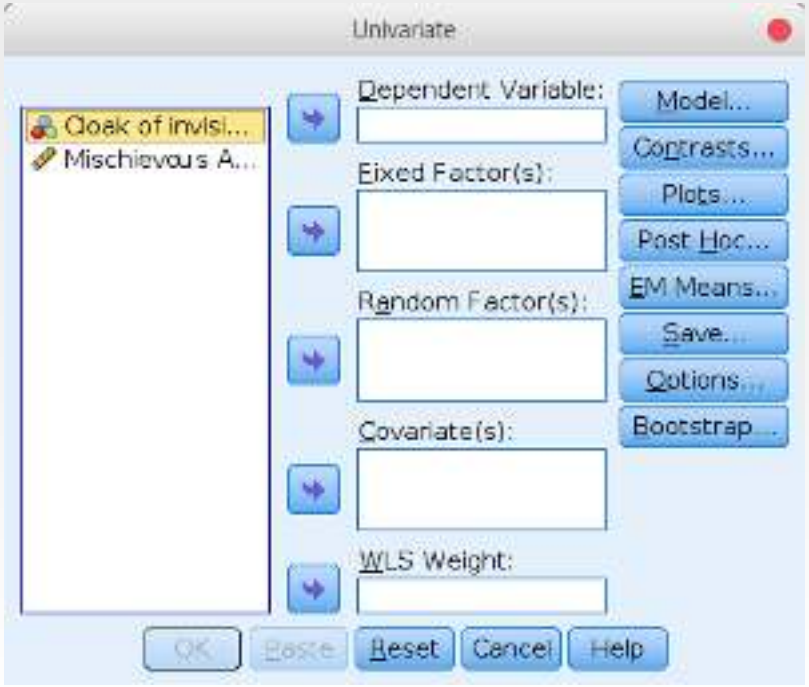


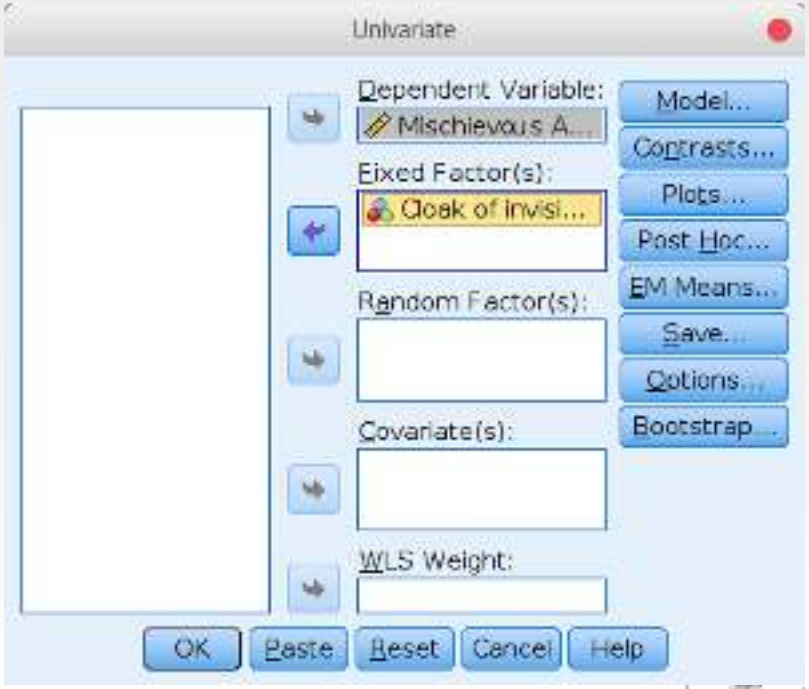


From t-test to ANOVA

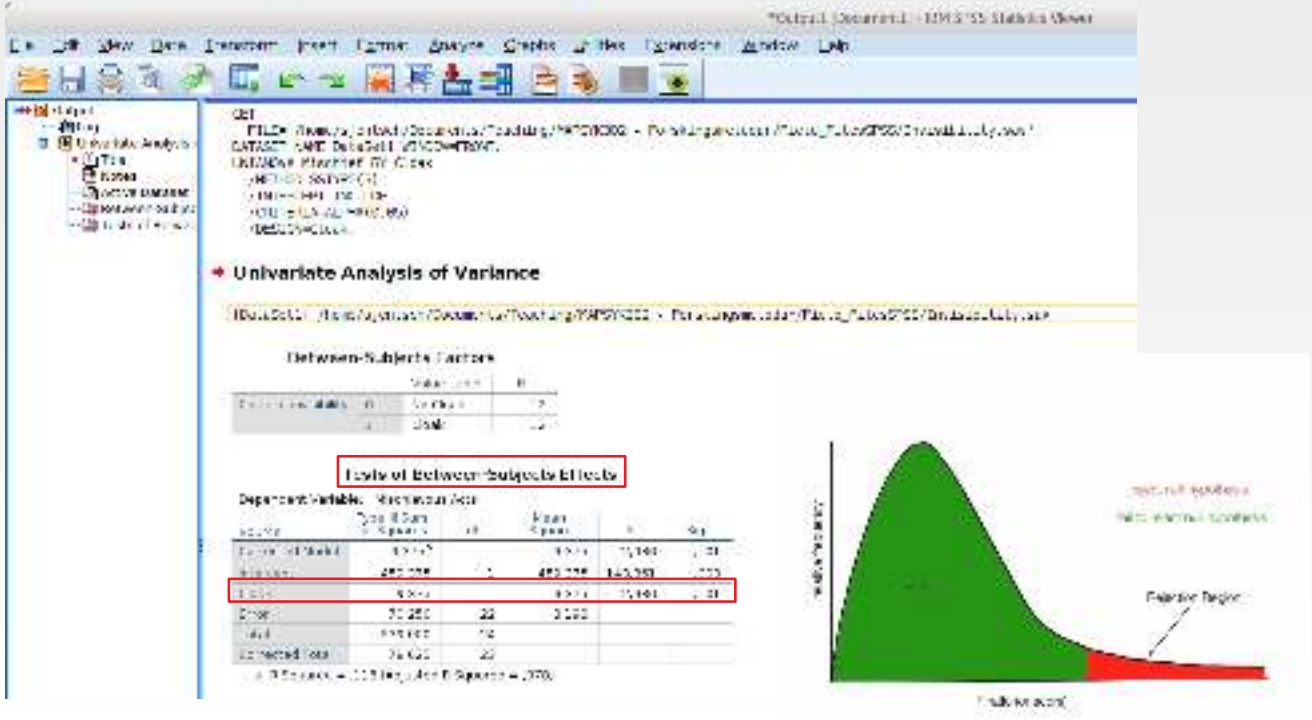


From t-test to ANOVA





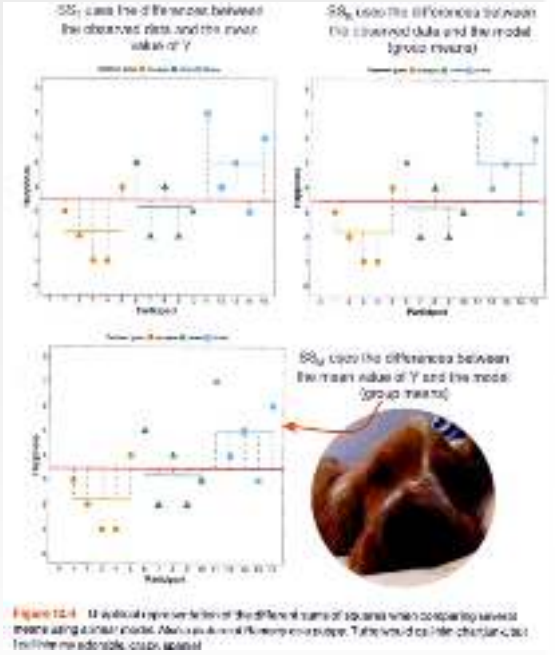
From t-test to ANOVA



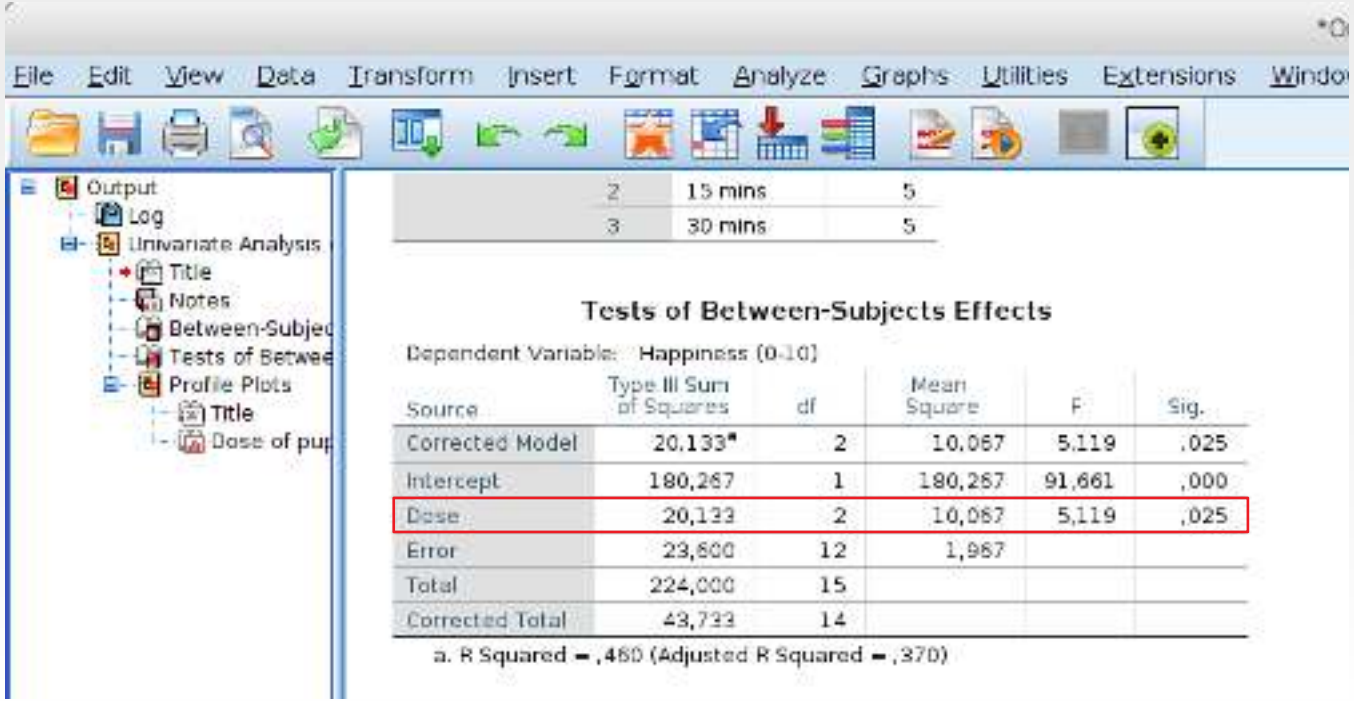
Questions?
Comments?

ANOVA: One factor

- ***Puppies.sav*** from Fields data set
  1 predictor (three step [Dose]) – 1 dependent variable [Happiness]:
- → Analyze → Descriptive Statistics → Explore
  (switch on Boxplots and Normality plots under Plots)
- → Analyze → General Linear Model → Univariate…
  (+ Plots and Contrasts to help interpreting the results)



ANOVA: One factor



2	15 mins	5
3	30 mins	5

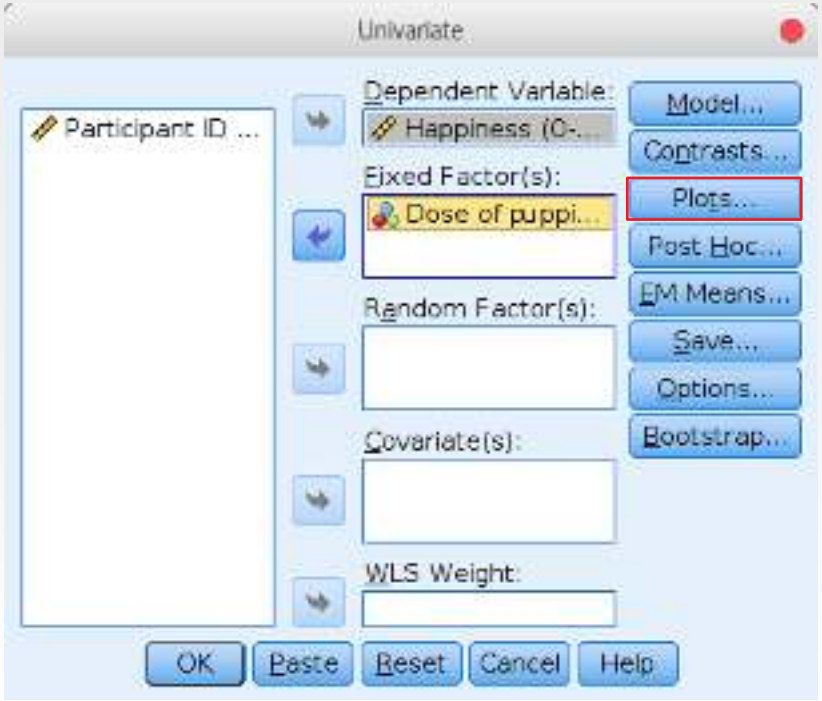
Tests of Between-Subjects Effects

Dependent Variable: Happiness (0-10)

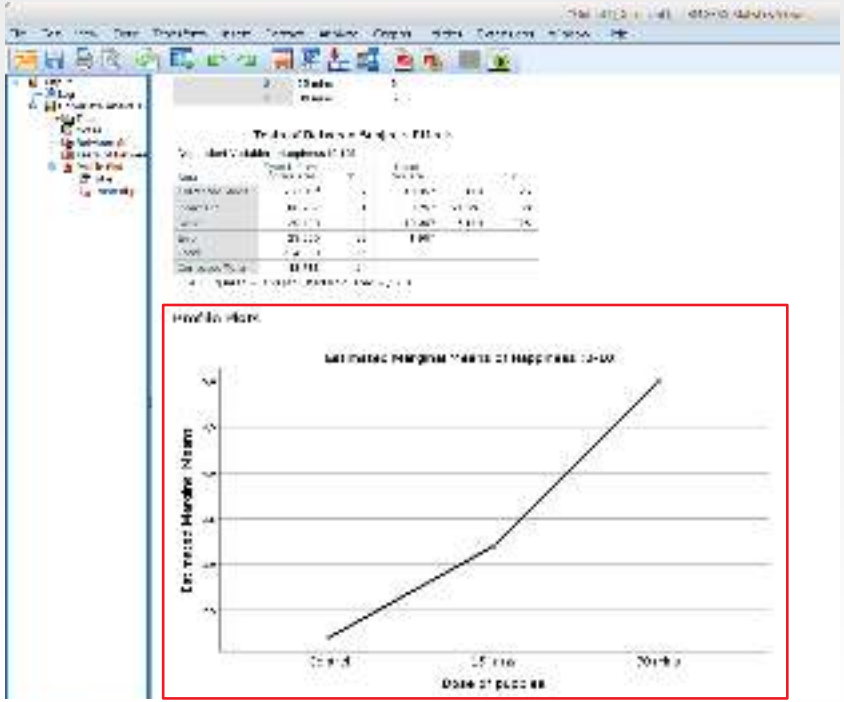
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	20,133[a]	2	10,067	5,119	,025
Intercept	180,267	1	180,267	91,661	,000
Dose	20,133	2	10,067	5,119	,025
Error	23,600	12	1,967		
Total	224,000	15			
Corrected Total	43,733	14			

a. R Squared = ,460 (Adjusted R Squared = ,370)

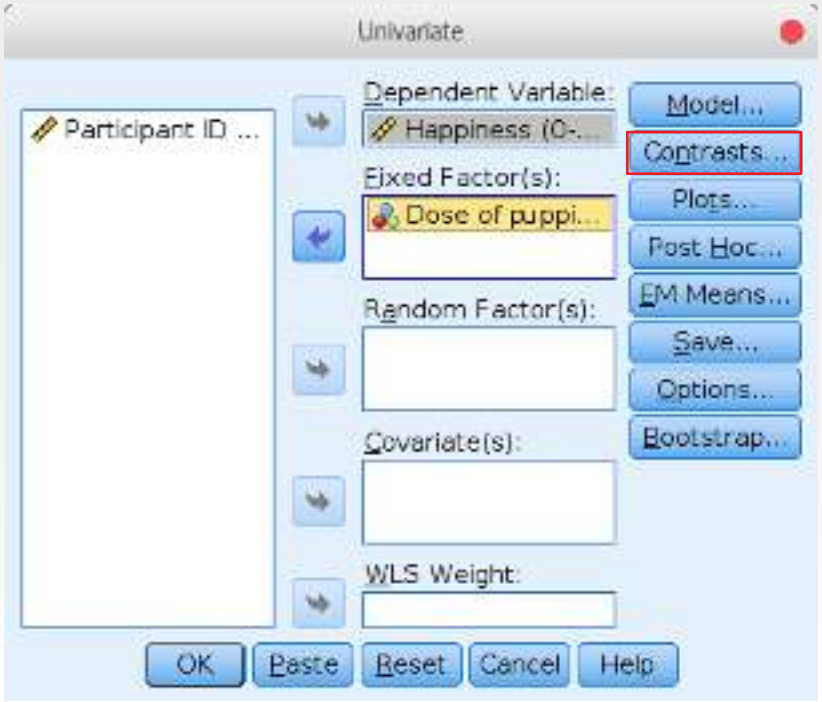
ANOVA: One factor

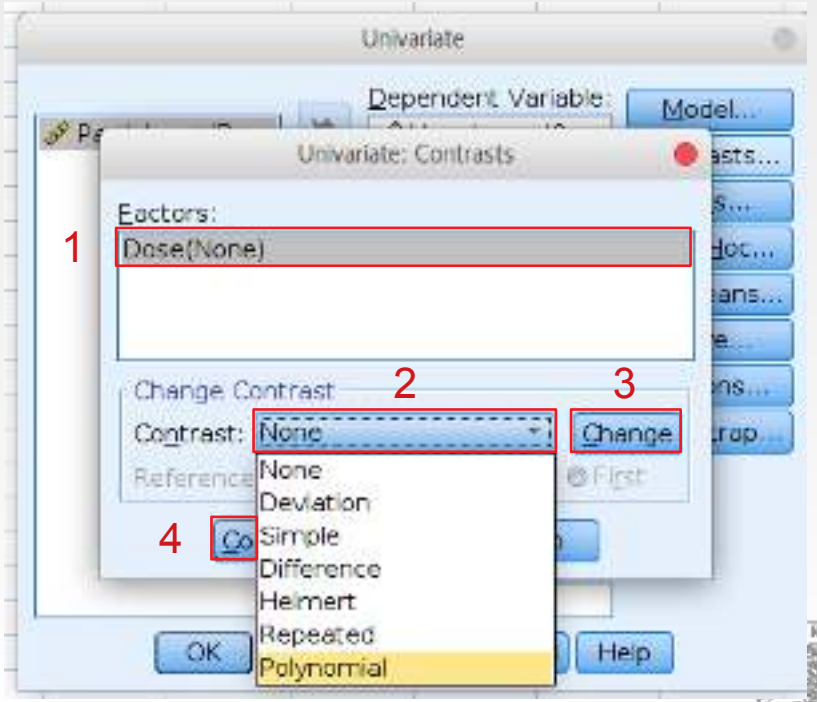


ANOVA: One factor

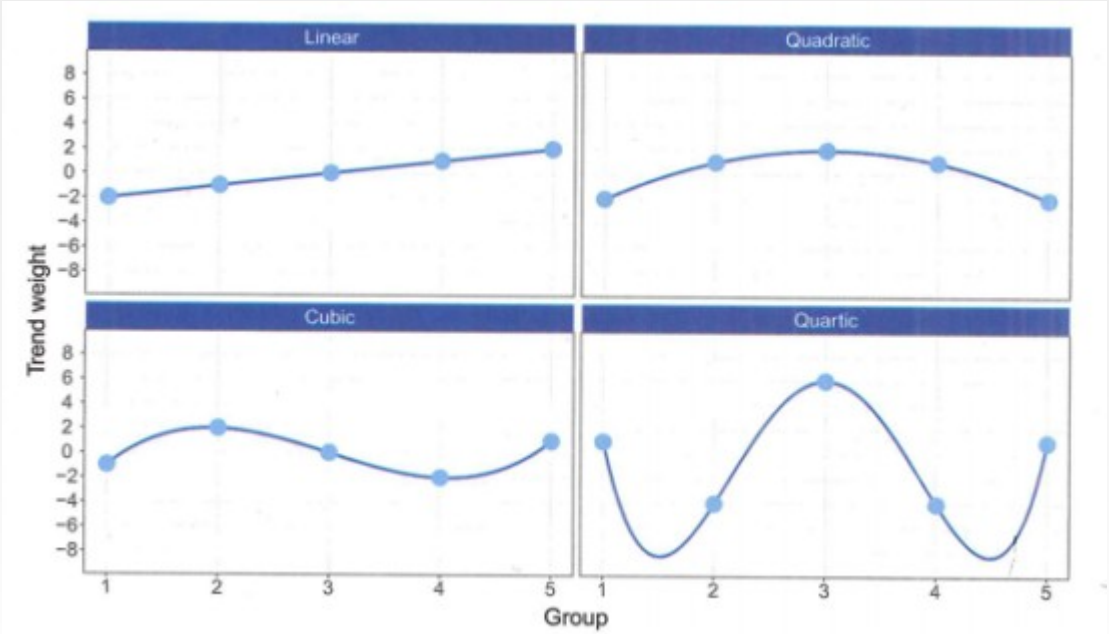


ANOVA: One factor





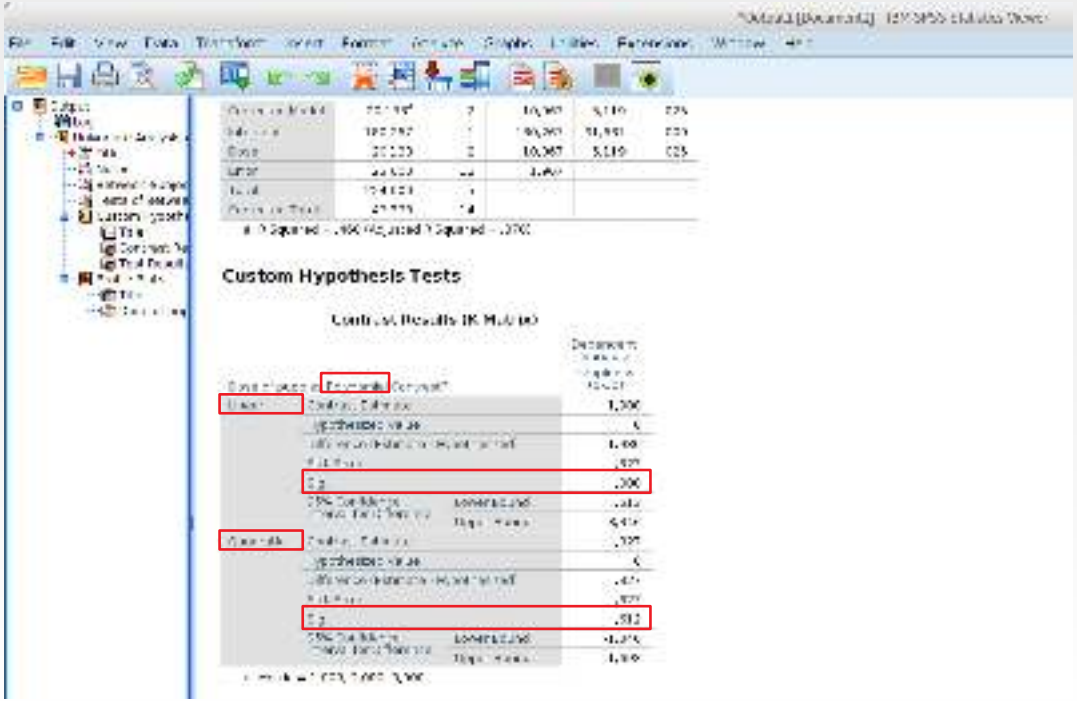
ANOVA: One factor



the number of factor steps determines the number of inflection points

Different polynomial contrasts to check for trends in the data

ANOVA: One factor



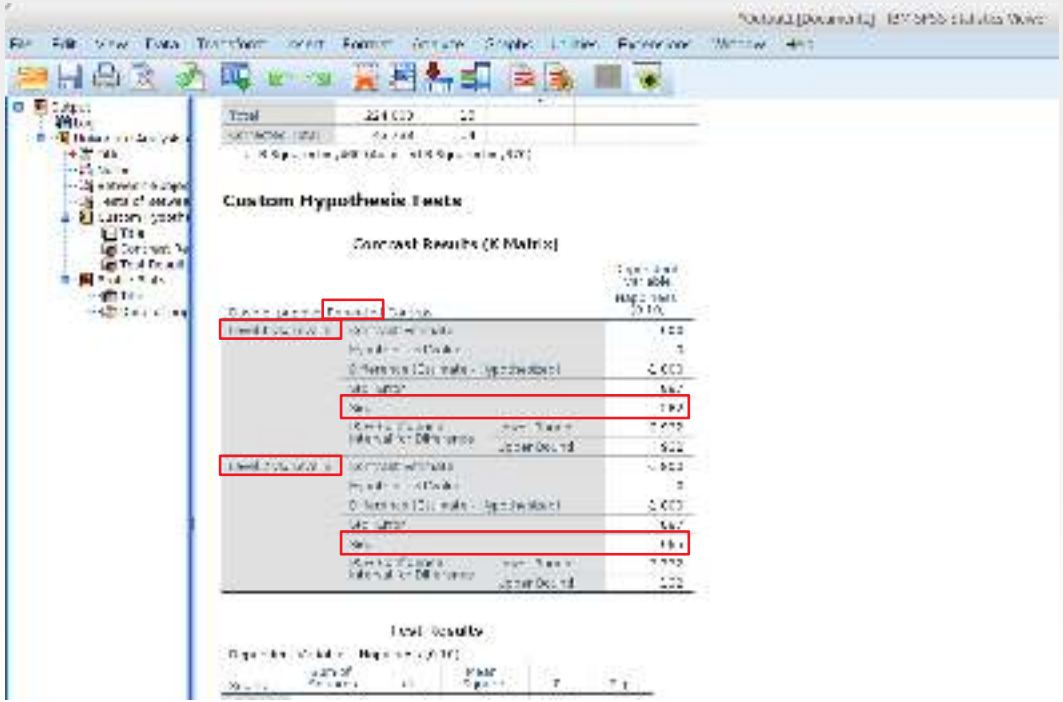
ANOVA: One factor

- Contrasts to compare different stages of the data

Table 12.8 Standard contrasts available in SPSS

Name	Definition	Contrast	Three Groups	Four Groups
Deviation (first)	Compares the effect of each category (except the first) to the overall experimental effect	1	2 vs. (1, 2, 3)	2 vs. (1, 2, 3, 4)
		2	3 vs. (1, 2, 3)	3 vs. (1, 2, 3, 4)
		3		4 vs. (1, 2, 3, 4)
Deviation (last)	Compares the effect of each category (except the last) to the overall experimental effect	1	1 vs. (1, 2, 3)	1 vs. (1, 2, 3, 4)
		2	2 vs. (1, 2, 3)	2 vs. (1, 2, 3, 4)
		3		3 vs. (1, 2, 3, 4)
Simple (first)	Each category is compared to the first category	1	1 vs. 2	1 vs. 2
		2	1 vs. 3	1 vs. 3
		3		1 vs. 4
Simple (last)	Each category is compared to the last category	1	1 vs. 3	1 vs. 4
		2	2 vs. 3	2 vs. 4
		3		3 vs. 4
Repeated	Each category (except the first) is compared to the previous category	1	1 vs. 2	1 vs. 2
		2	2 vs. 3	2 vs. 3
		3		3 vs. 4
Helmert	Each category (except the last) is compared to the mean effect of all subsequent categories	1	1 vs. (2, 3)	1 vs. (2, 3, 4)
		2	2 vs. 3	2 vs. (3, 4)
		3		3 vs. 4
Difference (reverse Helmert)	Each category (except the first) is compared to the mean effect of all previous categories	1	3 vs. (2, 1)	4 vs. (3, 2, 1)
		2	2 vs. 1	3 vs. (2, 1)
		3		2 vs. 1

ANOVA: One factor



Questions?
Comments?

ANCOVA

using ancova.sav from TabachnikFidell_FilesSPSS:

The research described in Section 1 in Appendix 'Research Designs for Complete Examples' provides the data for this illustration of ANCOVA. The research question is whether or not the attitudes toward drugs are associated with current employment status and/or religious affiliation. Files are ANCOVA.*.

Attitude toward drugs (ATTDRUG) serves as the DV, with increasingly high scores reflecting more favorable attitudes. The two IVs, factorially combined, are current employment status (EMPLMNT) with two levels: (1) employed and (2) unemployed, and religious affiliation (RELIGION) with four levels: (1) none-or-other, (2) Catholic, (3) Protestant, and (4) Jewish.

In examining other data for this sample of women, three variables stand out that could be expected to relate to attitudes toward drugs and might obscure effects of employment status and religion. These variables are general state of physical health, mental health, and the use of psychotropic drugs. In order to control for the effects of these three variables on attitudes toward drugs, they are treated as CVs. CVs, then, are physical health (PHYHEAL), mental health (MNTHEAL), and sum of all psychotropic drug uses, prescription and over-the-counter (PSYDRUG). For all three CVs, larger scores reflect increasingly poor health or more use of drugs.

The 2 × 4 analysis of covariance, then, provides a test of the effects of employment status, religion, and their interaction on attitudes toward drugs after adjustment for differences in physical health, mental health, and use of psychotropic drugs. Note that this is a form of ANCOVA in which no causal inference can be made.

ANCOVA

using ancova.sav from TabachnikFidell_FilesSPSS:
check assumptions (missing data, normality, linearity)
Analyze → Descriptive statistics → Explore (ATTDRUG PHYHEAL MENHEAL PSYDRUG as DV, EMPLMNT, RELIGION as factors)
→ some violations of normality because of skewed distributions (all positive, small values) and some outliers → logarithmize PHYHEAL and PSYDRUG

```
COMPUTE lphyheal=LG10(phyheal).
COMPUTE lpsydrug=LG10(psydrug + 1).
EXECUTE.
```

ANCOVA

using ancova.sav from TabachnikFidell_FilesSPSS:

Analyze → General Linear Model → Univariate
ATTDRUG as DV, EMPLMNT RELIGION as IVs;
LPHYHEAL MENHEAL LPSYDRUG as CVs
(a) Model: Sum of squares → Type I
(b) Plots: religion (h) * employment (l), error bars: SEM
(c) EM Means: all effects and interactions
(d) Options: Descriptives, Effect size

ANCOVA

Tests of Between-Subjects Effects

Dependent Variable: Attitude toward use of drugs

Source	Type I Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	78,683[a]	10	7,868	6,581	,000	,127
Intercept	27278,139	1	27278,139	22817,000	,000	,981
lphyheal	9,908	1	9,908	8,288	,004	,018
menheal	,134	1	,134	,112	,738	,000
lpsydrug	45,725	1	45,725	38,247	,000	,078
emplmnt	4,200	1	4,200	3,513	,062	,008
religion	9,844	3	3,281	2,745	,043	,018
emplmnt * religion	8,871	3	2,957	2,473	,061	,016
Error	539,179	451	1,196			
Total	27896,000	462				
Corrected Total	617,861	461				

a. R Squared = ,127 (Adjusted R Squared = ,108)

ANCOVA

Tests of Between-Subjects Effects

Dependent Variable: Attitude toward use of drugs

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	78,683[a]	10	7,868	6,581	,000	,127
Intercept	2196,974	1	2196,974	1837,675	,000	,803
lphyheal	,630	1	,630	,527	,468	,001
menheal	1,429	1	1,429	1,195	,275	,003
lpsydrug	46,737	1	46,737	39,094	,000	,080
emplmnt	1,080	1	1,080	,903	,342	,002
religion	12,194	3	4,065	3,400	,018	,022
emplmnt * religion	8,871	3	2,957	2,473	,061	,016
Error	539,179	451	1,196			
Total	27896,000	462				
Corrected Total	617,861	461				

a. R Squared = ,127 (Adjusted R Squared = ,108)

Questions?
Comments?

MANOVA and MANCOVA

using manova.sav from TabachnikFidell_FilesSPSS

In the research described in Appendix "Research Designs for Complete Examples", Section 1, there is interest in whether the means of several of the variables differ as a function of sex role identification. Are there differences in self-esteem, introversion–extraversion, neuroticism, and so on associated with a woman's masculinity and femininity? Files are MANOVA.*.

Sex role identification is defined by the masculinity and femininity scales of the Bem Sex Role Inventory (Bem, 1974). Each scale is divided at its median to produce two levels of masculinity (high and low), two levels of femininity (high and low), and four groups: Undifferentiated (low femininity, low masculinity), Feminine (high femininity, low masculinity), Masculine (low femininity, high masculinity), and Androgynous (high femininity, high masculinity). The design produces a main effect of masculinity, a main effect of femininity, and a masculinity–femininity interaction.[13]

DVs for this analysis are self-esteem (ESTEEM), internal versus external locus of control (CONTROL), attitudes toward women's role (ATTROLE), socioeconomic level (SEL2), introversion–extraversion (INTEXT), and neuroticism (NEUROTIC). Scales are coded so that higher scores generally represent the more "negative" trait:low self-esteem, greater neuroticism, etc.

Omnibus MANOVA (Section 6.2) asks whether these DVs are associated with the two IVs (femininity and masculinity) or their interaction. The Roy–Bargmann stepdown analysis, in conjunction with the univariate *F* values, allows us to examine the pattern of relationships between DVs and each IV.

MANOVA and MANCOVA

using manova.sav from TabachnikFidell_FilesSPSS

- **check for univariate outliers:**

```
SPLIT FILE SEPARATE BY ANDRM.
FREQUENCIES VARIABLES=ESTEEM CONTROL ATTROLE SEL2 INTEXT NEUROTIC
  /FORMAT=NOTABLE
  /STATISTICS=MEAN STDDEV VARIANCE MINIMUM MAXIMUM SKEWNESS KURTOSIS
  /ORDER=ANALYSIS.
```

Export tables to Excel / Calc and assess whether MIN and MAX are within the limits of MEAN +/- 3.3 SD

MANOVA and MANCOVA

using manova.sav from TabachnikFidell_FilesSPSS

- **check for multivariate outliers:**

```
SPLIT FILE SEPARATE BY ANDRM.
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT CASENO
  /METHOD=ENTER ESTEEM CONTROL ATTROLE SEL2 INTEXT NEUROTIC
  /RESIDUALS=OUTLIERS(MAHAL).
```

Check the «Outlier statistics»-table for statistics larger than 22.458 ($\rightarrow \chi^2_{(6)}$ for p = 0.001; p. 10)

MANOVA and MANCOVA

using manova.sav from TabachnikFidell_FilesSPSS

- **test for homegeneity of regression:**
  use syntax in MANOVA_HOR.sps on MittUIB
  check that the last effect in each model has a **p > 0.01** (usually it starts with POOL, for the first model with ESTEEM BY FEM...)

MANOVA and MANCOVA

using manova.sav from TabachnikFidell_FilesSPSS

- **carry out the MANOVA:**

```
MANOVA ESTEEM,ATTROLE,NEUROTIC,INTEXT,CONTROL,SEL2 BY FEM,MASC(1,2)
  /PRINT=SIGNIF(STEPDOWN), ERROR(COR), HOMOGENEITY(BARTLETT, COCHRAN, BOXM)
  /METHOD=SEQUENTIAL
  /DESIGN=FEM, MASC, FEM BY MASC.
```

- FEM and MASC are sign., the interaction isn't (check «Multivariate Tests of Significance»)
- assess «Univariate F-tests» and «Roy-Bargman Stepdown F-tests» in conjunction

MANOVA and MANCOVA

using manova.sav from TabachnikFidell_FilesSPSS

IV	DV	Univariate F	df	Stepdown F	df	α	Partial η^2	CL around Partial η^2 per α	
								Lower	Upper
Femininity	UNIDIM	8.13[b]	1/264	8.13[b]	1/264	.01	.02	.00	.05
	ATTROLE	15.73[a]	1/264	16.13[a]	1/263	.01	.05	.01	.12
	NEUROTIC	.79	1/264	0.16	1/263	.01	.00	.00	.01
	INTEXT	5.82[b]	1/264	3.82	1/263	.01	.01	.00	.05
	CONTROL	1.76	1/264	0.36	1/263	.01	.00	.00	.01
	SEL2	0.01	1/264	0.00	1/263	.01	.00	.00	.01
Masculinity	UNIDIM	76.16[a]	1/264	76.16[a]	1/264	.01	.18	.09	.27
	ATTROLE	35.79[a]	1/264	16.14[a]	1/263	.01	.05	.01	.12
	NEUROTIC	7.28[b]	1/264	0.19	1/263	.01	.00	.00	.01
	INTEXT	25.44[a]	1/264	11.13[a]	1/263	.01	.03	.00	.08
	CONTROL	7.39[b]	1/264	0.00	1/263	.01	.00	.00	.01
	SEL2	1.70	1/264	0.02	1/263	.01	.00	.00	.04
Femininity by masculinity interaction	UNIDIM	1.10	1/264	1.10	1/264	.01	.00	.00	.01
	ATTROLE	0.95	1/264	0.56	1/263	.01	.00	.00	.02
	NEUROTIC	0.01	1/264	0.12	1/263	.01	.00	.00	.01
	INTEXT	0.00	1/264	0.00	1/263	.01	.00	.00	.03
	CONTROL	0.56	1/264	0.32	1/263	.01	.00	.00	.02
	SEL2	0.54	1/264	0.46	1/263	.01	.00	.00	.04

[b] Significance level cannot be controlled for overall study ($p < .01$ in orthodox sense).
[a] $p < .01$.

1. Issues
   a. Unequal sample sizes and missing data
   b. Normality of sampling distributions
   c. Outliers
   d. Homogeneity of variance–covariance matrices
   e. Linearity
   f. In stepdown, when DVs act as covariates
      (1) Homogeneity of regression
      (2) Reliability of DVs
   g. Multicollinearity and singularity
2. Major analyses: Planned comparisons or omnibus F, when significant. Importance of DVs
   a. Within-cell correlations, stepdown F, univariate F
   b. Effect sizes with confidence interval for significant stepdown F
   c. Means or adjusted marginal means/cell means for significant F, with standard deviations, standard errors, or confidence intervals
3. Multivariate effect size(s) with confidence interval(s) for planned comparisons or omnibus F
4. Additional analyses
   a. Post hoc comparisons
   b. Interpretation of IV–covariate interaction (if homogeneity of regression violated)

Questions?
Comments?

MANOVA: Profile analysis

use profile.sav from TabachnikFidell_FilesSPSS

Variables are chosen from among those in the learning disabilities data bank described in Appendix 'Research Designs for Complete Examples', Section 2, to illustrate the application of profile analysis. Three groups are formed on the basis of the preference of learning-disabled children for age of playmates (AGEMATE): children whose parents report that they have (1) preference for playmates younger than themselves, (2) preference for playmates older than themselves, and (3) preference for playmates the same age as themselves or no preference. Data are in PROFILE.*.

DVs are the 11 subtests of the Wechsler Intelligence Scale for Children given either in its original or revised (WISC-R) form, depending on the date of administration of the test. The subtests are information (INFO), comprehension (COMP), arithmetic (ARITH), similarities (SIMIL), vocabulary (VOCAB), digit span (DIGIT), picture completion (PICTCOMP), picture arrangement (PARANG), block design (BLOCK), object assembly (OBJECT), and CODING.

The primary question is whether profiles of learning-disabled children on the WISC subscales differ if the children are grouped on the basis of their choice of age of playmates (the parallelism test). Secondary questions are whether preference for age of playmates is associated with overall IQ (the levels test), and whether the subtest pattern of the combined group of learning-disabled children is flat (the flatness test), as it is for the population on which the WISC was standardized.

MANOVA: Profile analysis

use profile.sav from TabachnikFidell_FilesSPSS

- **check for univariate outliers:**

```
SPLIT FILE SEPARATE BY agemate.
FREQUENCIES VARIABLES=info comp arith simil vocab digit pictcomp parang
block object coding
  /FORMAT=NOTABLE
  /STATISTICS=MEAN STDDEV VARIANCE MINIMUM MAXIMUM SKEWNESS KURTOSIS
  /ORDER=ANALYSIS.
```

Export tables to Excel / Calc and assess whether MIN and MAX are within the limits of MEAN +/- 3.3 SD → exclude case with arith = 19

MANOVA: Profile analysis

use profile.sav from TabachnikFidell_FilesSPSS

- **check for multivariate outliers:**

```
REGRESSION
  /MISSING LISTWISE
  /STATISTICS COEFF OUTS R ANOVA
  /CRITERIA=PIN(.05) POUT(.10)
  /NOORIGIN
  /DEPENDENT client
  /METHOD=ENTER info comp arith simil vocab digit pictcomp parang block
object coding
  /RESIDUALS=OUTLIERS(MAHAL).
```

Check the «Outlier statistics»-table for statistics larger than 31.264 ($\rightarrow \chi^2_{(11)}$ for p = 0.001; p. 10)

MANOVA: Profile analysis

use profile.sav from TabachnikFidell_FilesSPSS

- **define repeated-measures ANOVA:**
  Analyze → General Linear M. → Repeated meas.
  (a) repetition factor *subtest* (11), *agemate* as betw.
  (b) Plot: subtest (H) × agemate (S)
  (c) EM Means: all effects
  (d) Options: Descript., Effect size, Power, Homog.

MANOVA: Profile analysis

use profile.sav from TabachnikFidell_FilesSPSS

- **results from repeated-measures ANOVA:**
  (a) sign. effects of *subtest* and *subtest* × *agemate*
  (using multivariate and univariate tests [GG])
  (b) no sign. effect for *agemate* (between-subj.-eff.)

MANOVA: Profile analysis

use profile.sav from TabachnikFidell_FilesSPSS

- **assessing differences from population and calculate confidence interval for subtests:**

  (a) re-arrange and export Descriptive Statistics

  (b) calc. $z = \frac{\bar{Y} - \mu}{\sigma/\sqrt{N}} = \frac{9.55488 - 10}{3.0/\sqrt{164}} = -1.900$

  (assess differences betw. clin. groups / norm.)

  (c) calc.

$$P(\bar{Y} - zs_{\bar{Y}} < \mu < \bar{Y} + zs_{\bar{Y}}) = 99.85 \quad (11)$$

$$P(9.55488 - 3.19(3.03609)/\sqrt{164} < \mu < 9.55488 + 3.19(3.036091)/\sqrt{164} = 99.85$$

$$P(8.79860 < \mu < 10.31116) = 99.85$$

(subtest score over groups vs. per group)

MANOVA: Profile analysis

1. Issues
   a. Unequal sample sizes and missing data
   b. Normality of sampling distributions
   c. Outliers
   d. Homogeneity of variance–covariance matrices
   e. Linearity
   f. Multicollinearity and singularity
2. Major analysis
   a. Tests for parallelism. If significant: Figure showing profile for deviation from parallelism
   b. Test for differences among levels, if appropriate. If significant: Marginal means for groups and standard deviations or standard errors or confidence intervals
   c. Test for deviation from flatness, if appropriate. If significant: Means for measures and standard deviations or standard errors or confidence intervals
   d. Effect sizes with confidence limits for all three tests
3. Additional analyses
   a. Planned comparisons
   b. Post hoc comparisons appropriate for significant effect(s)
      (1) Comparisons among groups
      (2) Comparisons among measures
      (3) Comparisons among measures within groups
   c. Power analysis for nonsignificant effects

Questions?
Comments?

It’s your turn now!

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