REPEATED MEASURES ANOVA
for the analysis of ERP data

15th, April 2009
Advanced Statistics Seminar
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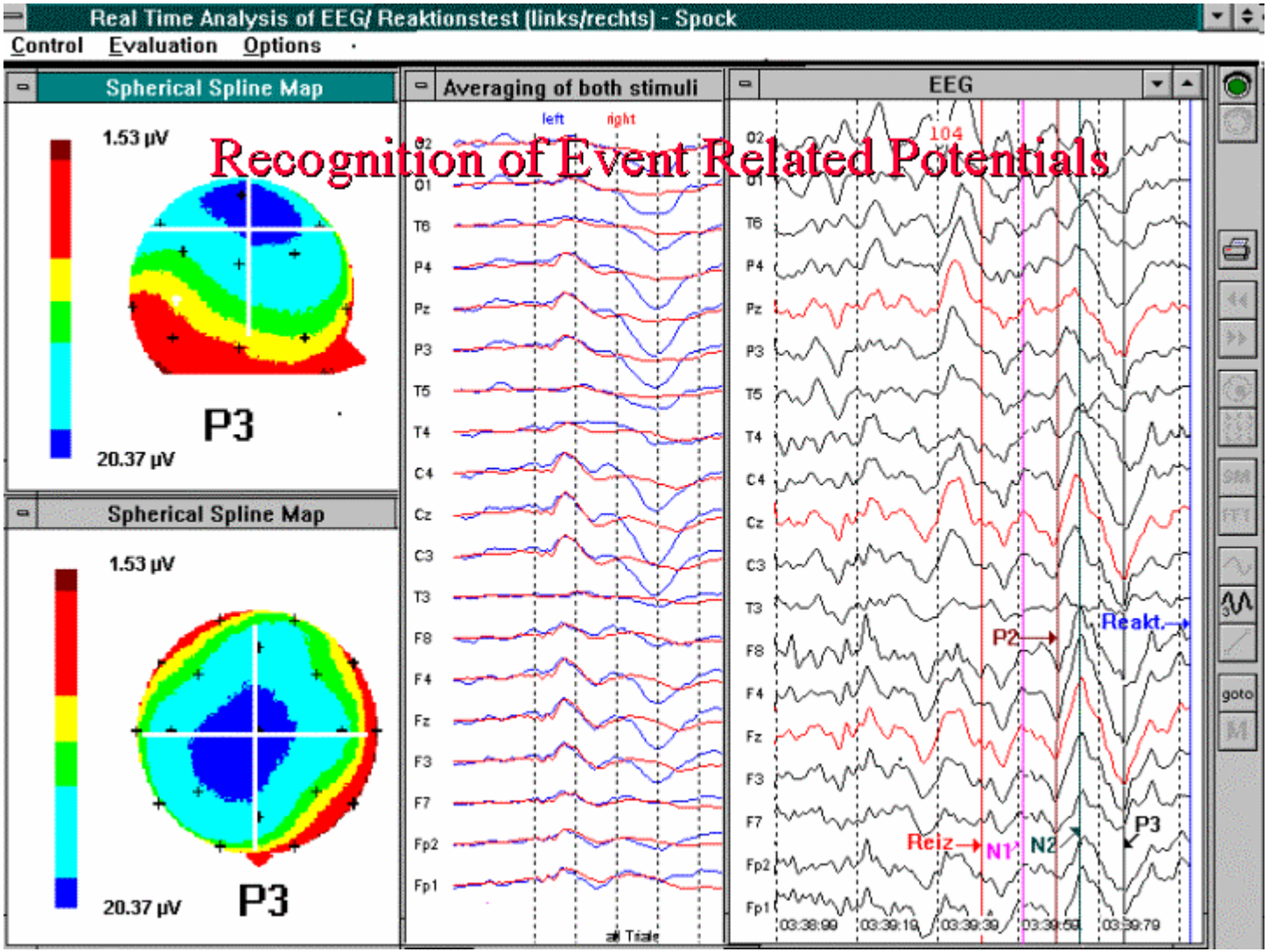
Outline

- What data have we got?
- What do we need to know about the repeated measures design?
- Repeated Measures in SPSS



Recognition of Event Related Potentials

Within subject or Between subject?

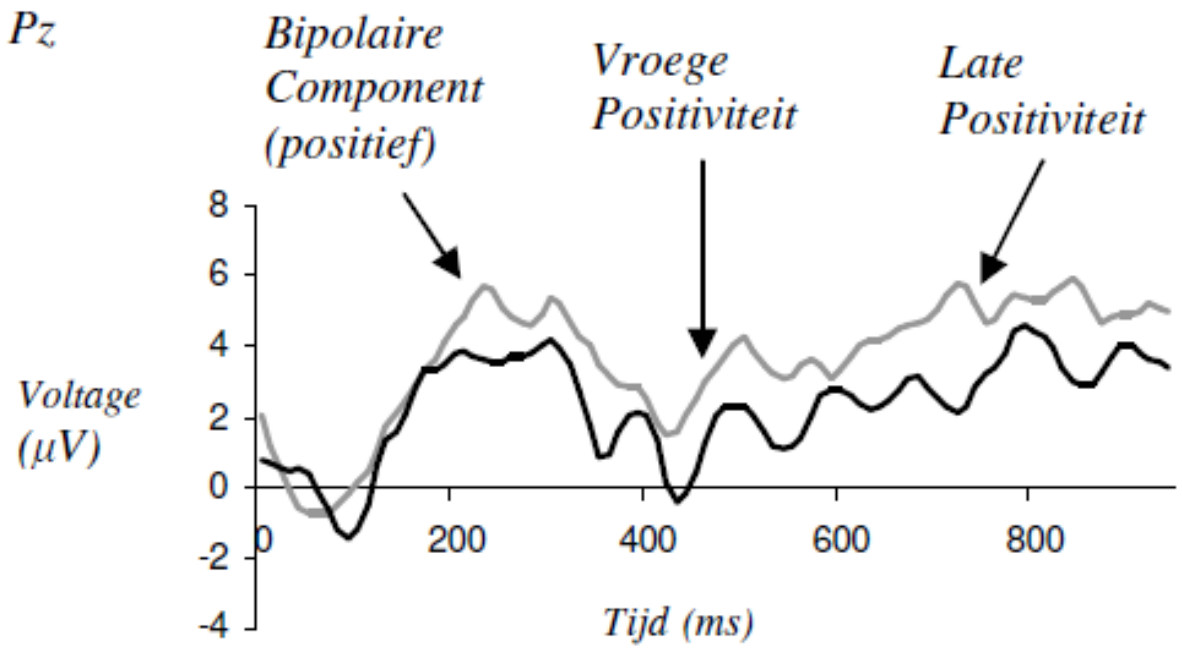
54 subjects

<u>Between subject:</u>
3 lists (18 subjects per list)

<u>Within subject</u>:
- Condition
- Anteriority
- Laterality

+ Time

Time – 3 levels



- 180-320 ms
- 350-550 ms
- 550-750 ms

Condition – 2 levels

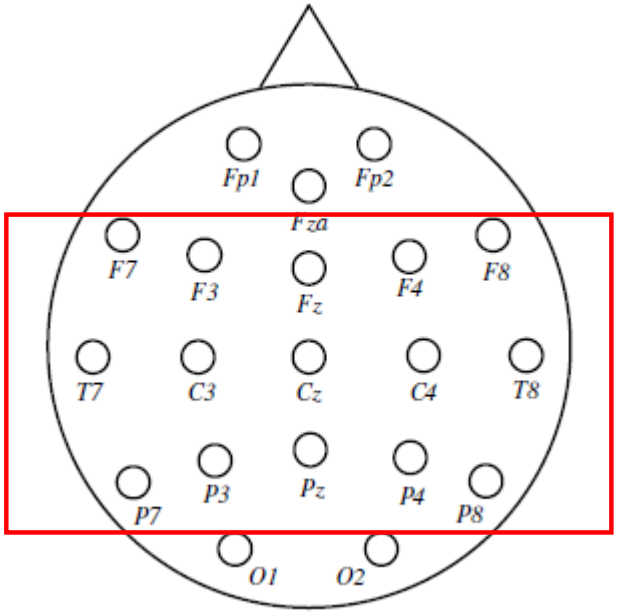
Neutral condition:

- Q: What happened?
- A: The mayor praised the councillor and the alderman exuberantly.

Violation condition:

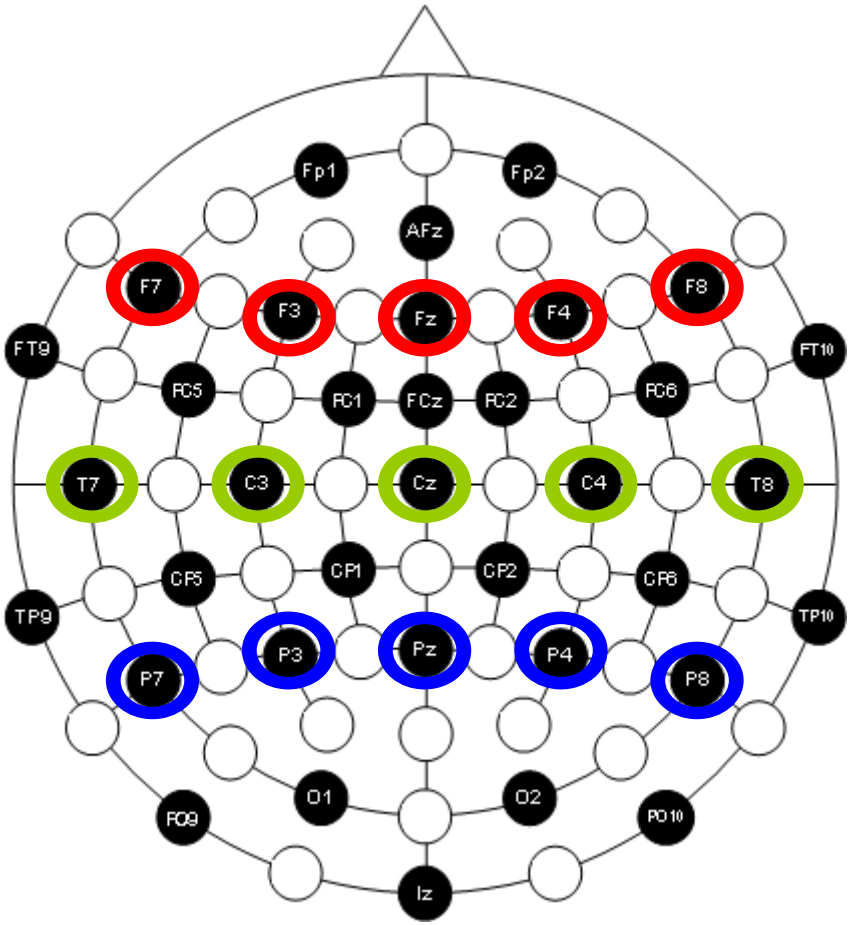
- Q: What did the mayor and the alderman do?
- A: The mayor praised the councillor and the alderman exuberantly.

Order of analysis (localization)

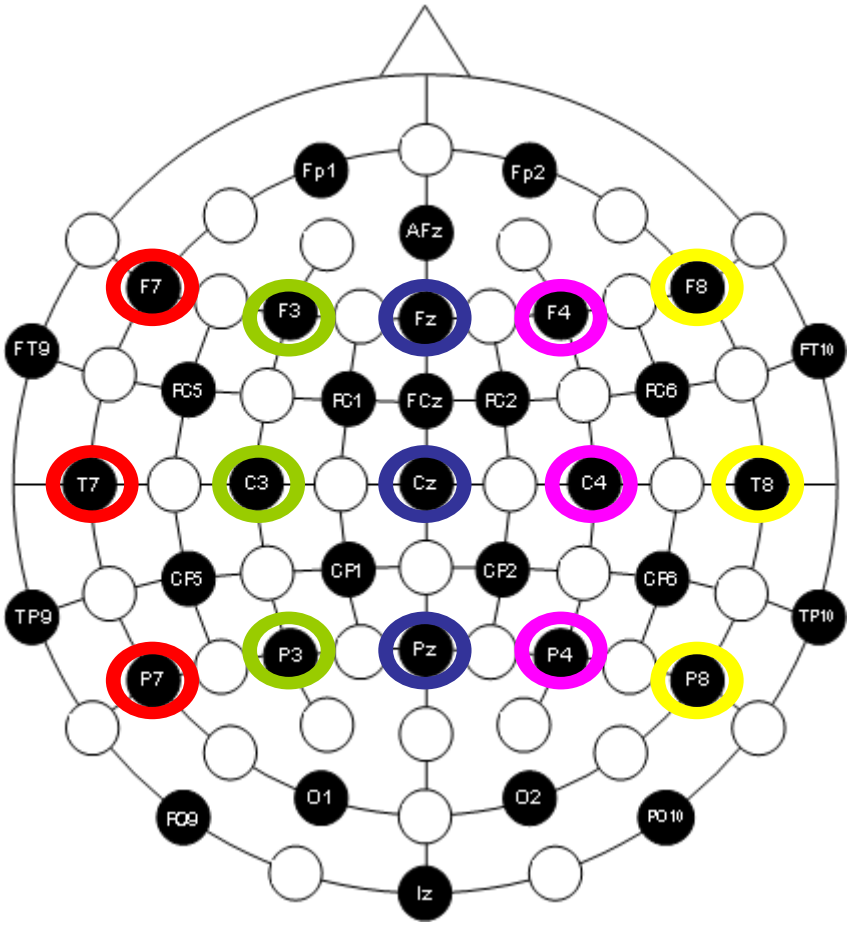


- Main electrode site
- Frontal electrodes
- Occipital electrodes

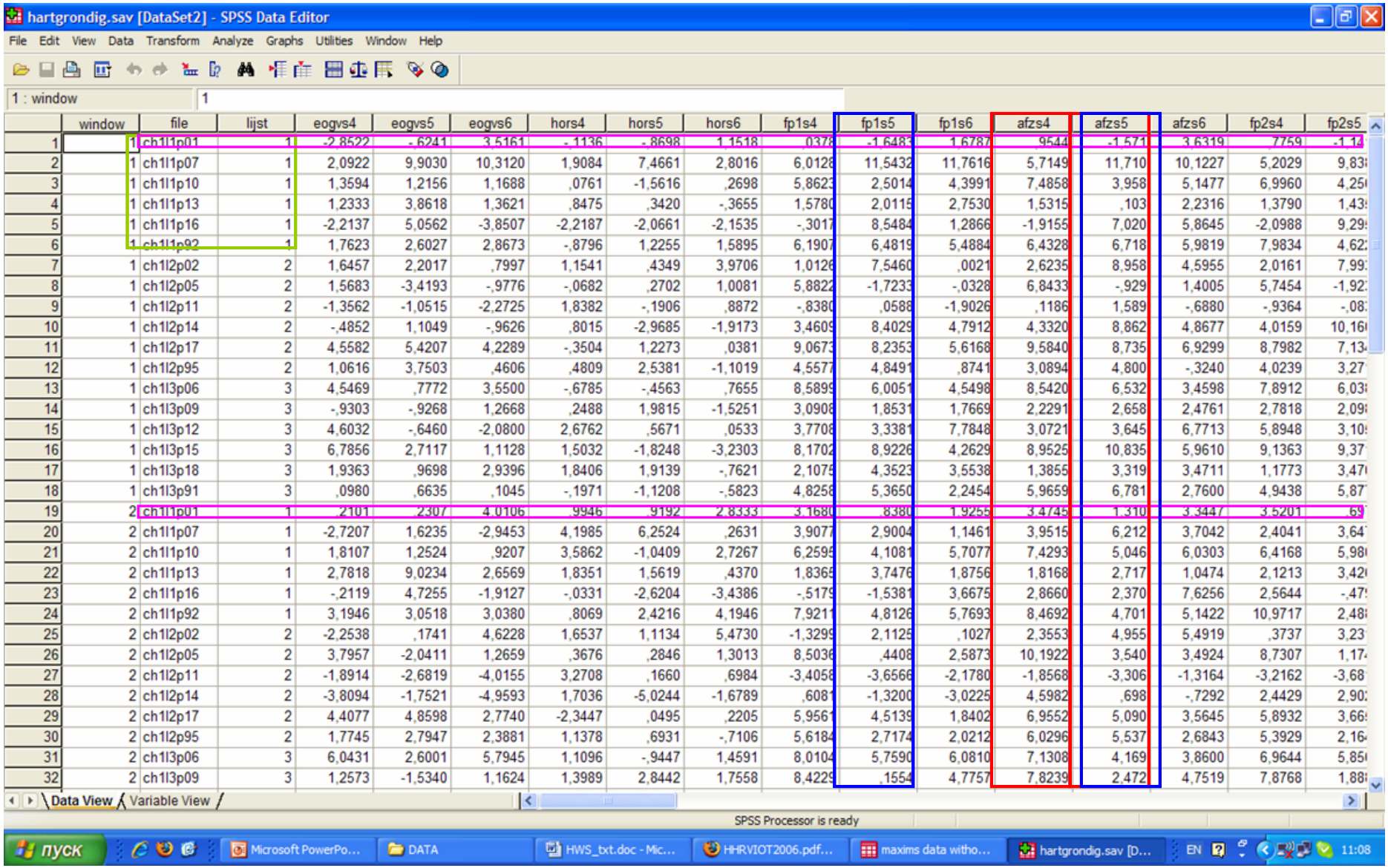
Anteriority – 3 levels



Laterality – 5 levels



Data in SPSS


hartgrondig.sav [DataSet2] - SPSS Data Editor
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1 : window
1
window file lijst eogvs4 eogvs5 eogvs6 hors4 hors5 hors6 fp1s4 fp1s5 fp1s6 afzs4 afzs5 afzs6 fp2s4 fp2s5
1 1 ch1l1p01 1 -2,8522 -,6241 3,5161 -,1136 -,8698 1,1518 ,0378 -1,6483 1,6787 ,9544 -1,571 3,6319 ,7759 -1,14
2 1 ch1l1p07 1 2,0922 9,9030 10,3120 1,9084 7,4661 2,8016 6,0128 11,5432 11,7616 5,7149 11,710 10,1227 5,2029 9,83
3 1 ch1l1p10 1 1,3594 1,2156 1,1688 ,0761 -1,5616 ,2698 5,8623 2,5014 4,3991 7,4858 3,958 5,1477 6,9960 4,25
4 1 ch1l1p13 1 1,2333 3,8618 1,3621 ,8475 ,3420 -,3655 1,5780 2,0115 2,7530 1,5315 ,103 2,2316 1,3790 1,43
5 1 ch1l1p16 1 -2,2137 5,0562 -3,8507 -2,2187 -2,0661 -2,1535 -,3017 8,5484 1,2866 -1,9155 7,020 5,8645 -2,0988 9,29
6 1 ch1l1p92 1 1,7623 2,6027 2,8673 -,8796 1,2255 1,5895 6,1907 6,4819 5,4884 6,4328 6,718 5,9819 7,9834 4,62
7 1 ch1l2p02 2 1,6457 2,2017 ,7997 1,1541 ,4349 3,9706 1,0126 7,5460 ,0021 2,6235 8,958 4,5955 2,0161 7,99
8 1 ch1l2p05 2 1,5683 -3,4193 -,9776 -,0682 ,2702 1,0081 5,8822 -1,7233 -,0328 6,8433 -,929 1,4005 5,7454 -1,92
9 1 ch1l2p11 2 -1,3562 -1,0515 -2,2725 1,8382 -,1906 ,8872 -,8380 ,0588 -1,9026 ,1186 1,589 -,6880 -,9364 -,08
10 1 ch1l2p14 2 -,4852 1,1049 -,9626 ,8015 -2,9685 -1,9173 3,4609 8,4029 4,7912 4,3320 8,862 4,8677 4,0159 10,16
11 1 ch1l2p17 2 4,5582 5,4207 4,2289 -,3504 1,2273 ,0381 9,0673 8,2353 5,6168 9,5840 8,735 6,9299 8,7982 7,13
12 1 ch1l2p95 2 1,0616 3,7503 ,4606 ,4809 2,5381 -1,1019 4,5577 4,8491 ,8741 3,0894 4,800 -,3240 4,0239 3,27
13 1 ch1l3p06 3 4,5469 ,7772 3,5500 -,6785 -,4563 ,7655 8,5899 6,0051 4,5498 8,5420 6,532 3,4598 7,8912 6,03
14 1 ch1l3p09 3 -,9303 -,9268 1,2668 ,2488 1,9815 -1,5251 3,0908 1,8531 1,7669 2,2291 2,658 2,4761 2,7818 2,09
15 1 ch1l3p12 3 4,6032 -,6460 -2,0800 2,6762 ,5671 ,0533 3,7708 3,3381 7,7848 3,0721 3,645 6,7713 5,8948 3,10
16 1 ch1l3p15 3 6,7856 2,7117 1,1128 1,5032 -1,8248 -3,2303 8,1702 8,9226 4,2629 8,9525 10,835 5,9610 9,1363 9,37
17 1 ch1l3p18 3 1,9363 ,9698 2,9396 1,8406 1,9139 -,7621 2,1075 4,3523 3,5538 1,3855 3,319 3,4711 1,1773 3,47
18 1 ch1l3p91 3 ,0980 ,6635 ,1045 -,1971 -1,1208 -,5823 4,8258 5,3650 2,2454 5,9659 6,781 2,7600 4,9438 5,87
19 2 ch1l1p01 1 ,2101 ,2307 4,0106 ,9946 ,9192 2,8333 3,1680 ,8380 1,9255 3,4745 1,310 3,3447 3,5201 ,69
20 2 ch1l1p07 1 -2,7207 1,6235 -2,9453 4,1985 6,2524 ,2631 3,9077 2,9004 1,1461 3,9515 6,212 3,7042 2,4041 3,64
21 2 ch1l1p10 1 1,8107 1,2524 ,9207 3,5862 -1,0409 2,7267 6,2595 4,1081 5,7077 7,4293 5,046 6,0303 6,4168 5,98
22 2 ch1l1p13 1 2,7818 9,0234 2,6569 1,8351 1,5619 ,4370 1,8365 3,7476 1,8756 1,8168 2,717 1,0474 2,1213 3,42
23 2 ch1l1p16 1 -,2119 4,7255 -1,9127 -,0331 -2,6204 -3,4386 -,5179 -1,5381 3,6675 2,8660 2,370 7,6256 2,5644 -,47
24 2 ch1l1p92 1 3,1946 3,0518 3,0380 ,8069 2,4216 4,1946 7,9211 4,8126 5,7693 8,4692 4,701 5,1422 10,9717 2,48
25 2 ch1l2p02 2 -2,2538 ,1741 4,6228 1,6537 1,1134 5,4730 -1,3299 2,1125 ,1027 2,3553 4,955 5,4919 ,3737 3,23
26 2 ch1l2p05 2 3,7957 -2,0411 1,2659 ,3676 ,2846 1,3013 8,5036 ,4408 2,5873 10,1922 3,540 3,4924 8,7307 1,17
27 2 ch1l2p11 2 -1,8914 -2,6819 -4,0155 3,2708 ,1660 ,6984 -3,4058 -3,6566 -2,1780 -1,8568 -3,306 -1,3164 -3,2162 -3,68
28 2 ch1l2p14 2 -3,8094 -1,7521 -4,9593 1,7036 -5,0244 -1,6789 ,6081 -1,3200 -3,0225 4,5982 ,698 -,7292 2,4429 2,90
29 2 ch1l2p17 2 4,4077 4,8598 2,7740 -2,3447 ,0495 ,2205 5,9561 4,5139 1,8402 6,9552 5,090 3,5645 5,8932 3,66
30 2 ch1l2p95 2 1,7745 2,7947 2,3881 1,1378 ,6931 -,7106 5,6184 2,7174 2,0212 6,0296 5,537 2,6843 5,3929 2,16
31 2 ch1l3p06 3 6,0431 2,6001 5,7945 1,1096 -,9447 1,4591 8,0104 5,7590 6,0810 7,1308 4,169 3,8600 6,9644 5,85
32 2 ch1l3p09 3 1,2573 -1,5340 1,1624 1,3989 2,8442 1,7558 8,4229 ,1554 4,7757 7,8239 2,472 4,7519 7,8768 1,88
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So what do we want to know?

- How much variance between subject is explained by variance within subject?
- Is our manipulation effecting participants similarly (there is a trend) or is it just an individual reaction?

$$F = \frac{(\text{explained variance})}{(\text{unexplained variance})}, \qquad F = \frac{(\text{between-group variability})}{(\text{within-group variability})},$$

- Why do we want to know that?

$$E(MS_{\text{within}}) = \sigma_\varepsilon^2 \qquad (14)$$

- Variance within subject.

$$\text{if } H_0 \text{ is true}: \quad E(MS_{\text{between}}) = \sigma_\varepsilon^2 \qquad (15)$$

F < 1

$$\text{if } H_1 \text{ is true}: \quad E(MS_{\text{between}}) = \sigma_\varepsilon^2 + n\sigma_\alpha^2 \qquad (16)$$

F > 1

How to calculate variance?

Squared deviations of X from the mean

(x=X - $\bar{X}$)

$\sum X^2$ - Sum of Squares – the deviation sum of squares.

The SS grows with the size of the data collection.

To scale (normalize) – divide by degrees of freedom.

$$\sum_{i=1}^{n} \left(X_i - \overline{X}\right)^2$$

variability

variance

$$s_x^2 = \frac{\sum_{i=1}^{n}(X - \bar{X})^2}{n-1} = \frac{\sum_{i=1}^{n} x^2}{n-1} \qquad (6)$$

Sums of squared deviations

- I - total squared deviations
- T- treatment squared deviations
- C -residual squared deviations
- The constants ($n - 1$), ($k - 1$), and ($n - k$) are normally referred to as the number of degrees of freedom.
- In a very simple example, 5 observations arise from two treatments. The first treatment gives three values 1, 2, and 3, and the second treatment gives two values 4, and 6.

$$I = \frac{1^2}{1} + \frac{2^2}{1} + \frac{3^2}{1} + \frac{4^2}{1} + \frac{6^2}{1} = 66$$

$$T = \frac{(1+2+3)^2}{3} + \frac{(4+6)^2}{2} = 12 + 50 = 62$$

$$C = \frac{(1+2+3+4+6)^2}{5} = 256/5 = 51.2$$

  - Total squared deviations = 66 − 51.2 = 14.8 with 4 degrees of freedom.
  - Treatment squared deviations = 62 − 51.2 = 10.8 with 1 degree of freedom.
  - Residual squared deviations = 66 − 62 = 4 with 3 degrees of freedom.

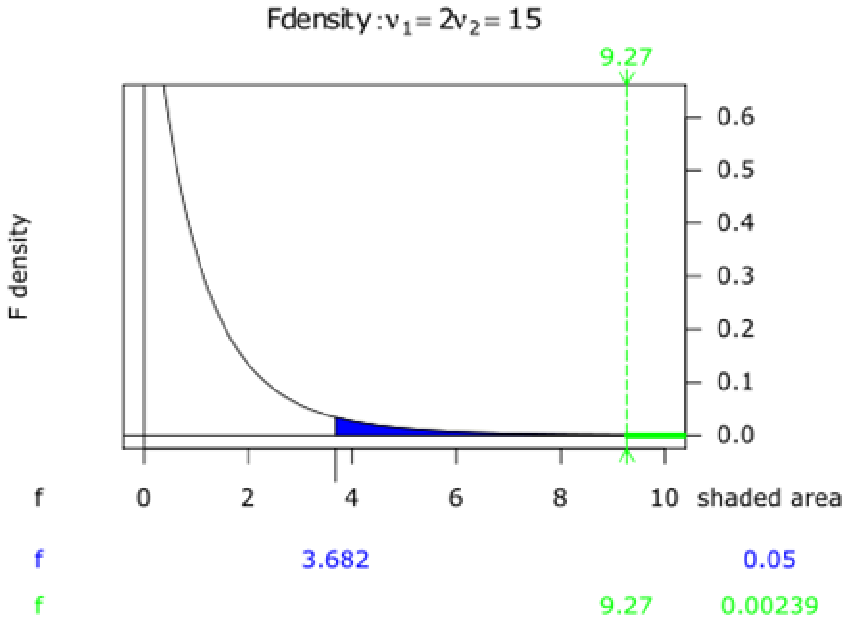
More facts about F

- George W. Snedecor

  Sir Ronald A. Fisher

  the variance ratio

  1920s
- The hypothesis of F-test: “the means of multiple normally distributed populations, all having the same standard deviation, are equal”.
- F-test is extremely non-robust to non-normality.



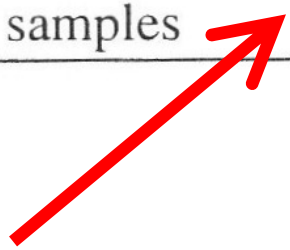
Which ANOVA to choose?

3 lists = 3 levels

Table 1.2. Four basic designs based on the properties of the independent variable

independent variable	two levels	more than two levels
between-subject factor	*design 1* *t* test independent samples	*design 3* one-way ANOVA
within-subject factor	*design 2* *t* test correlated samples	*design 4* repeated measures ANOVA

Condition (2)
Anteriority (3)
Laterality (5)



Why Repeated measures?

(`within-subjects design',
`randomized blocks design‘)

- Economy of subjects, time and effort.

  One-way ANOVA with *p* levels of factor A and *n* observations per cell requires pn subjects *n* or 1/*p* as many subjects.

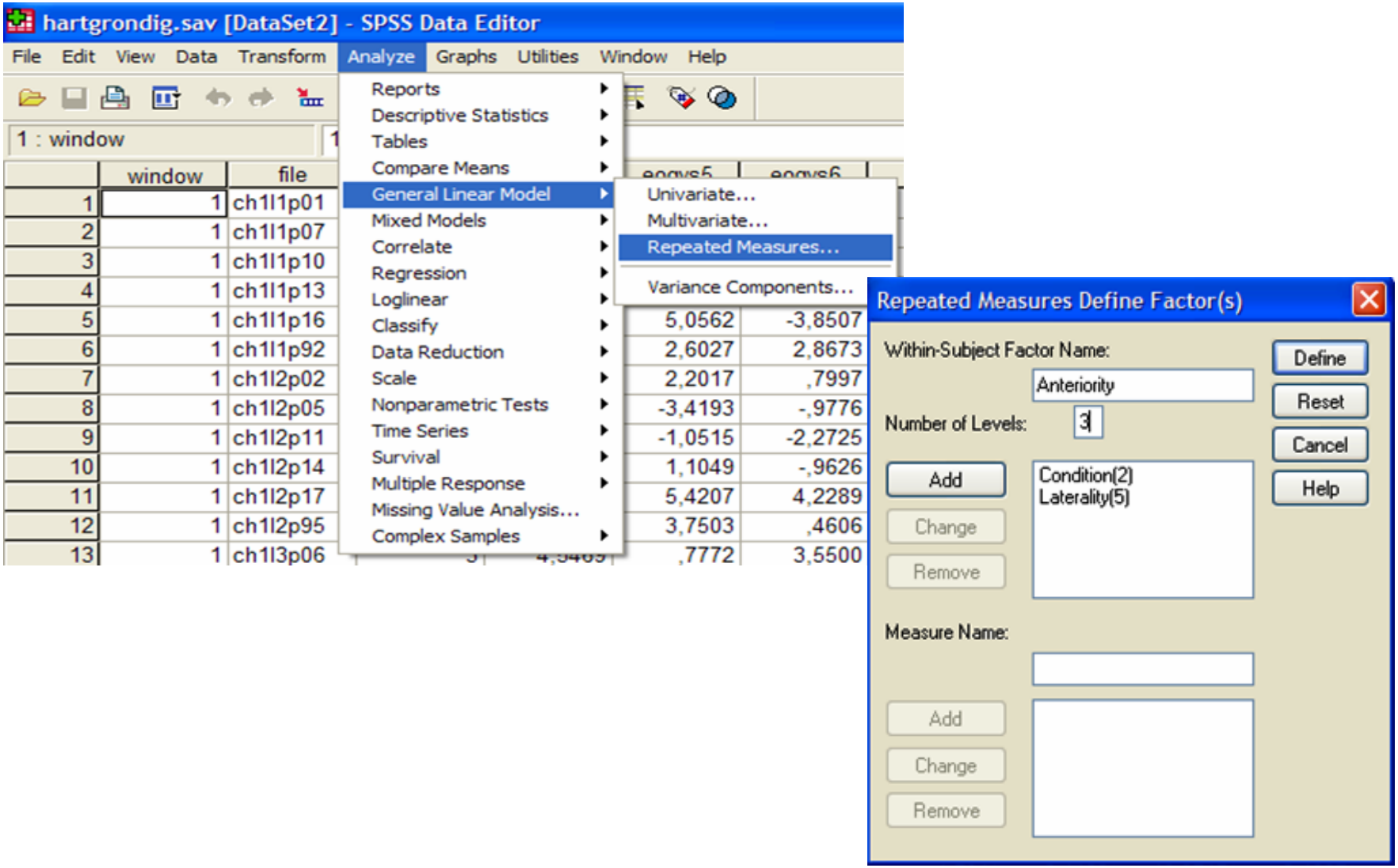
- Allows to pose interesting questions:

  what happens to people as they move through time, space and circumstances?

- Controlling for unique subject effect.

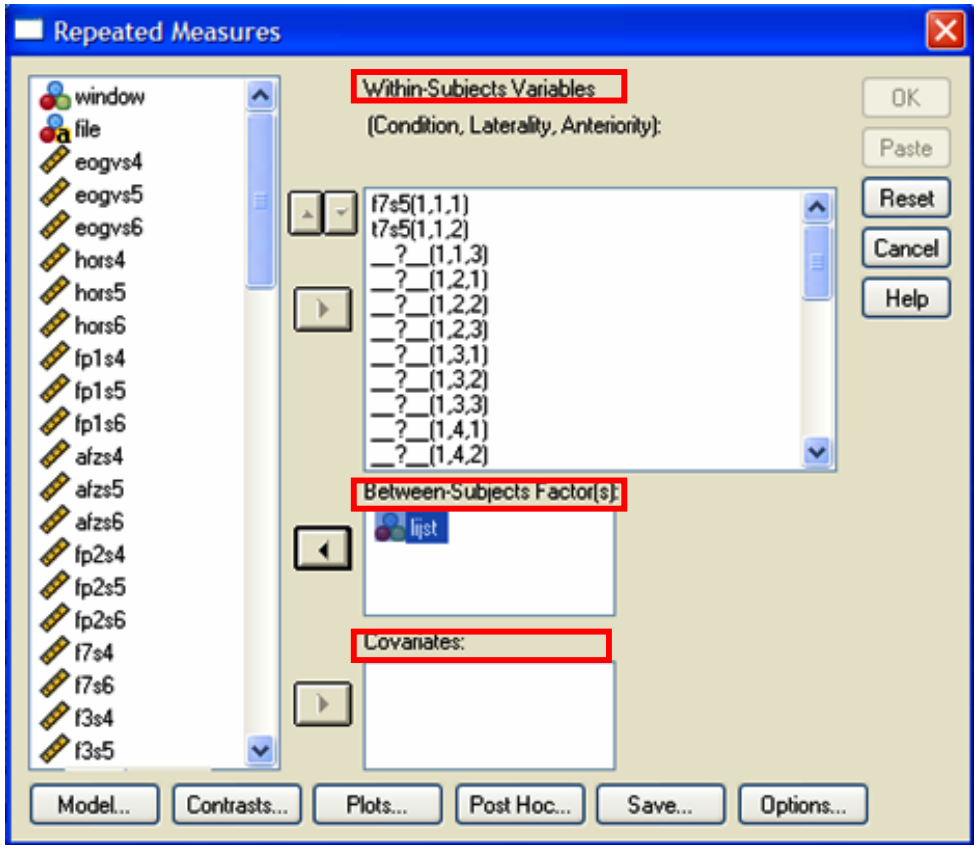
  Treating each subject as a block, each subjects serves as his/her own control.

SPSS GLM Repeated measures



Data

- Within-subject variables should be quantitative.
- Between-subjects factors are categorical, they divide the sample into discrete subgroups, such as male and female.
- Covariates are quantitative variables that are related to the dependent variable.



Within-Subjects Factors			
Measure:MEASURE_1			
condition	anteriority	Laterality	Dependent Variable
1	1	1	f7s4
		2	f3s4
		3	fzs4
		4	f4s4
		5	f8s4
	2	1	t7s4
		2	c3s4
		3	czs4
		4	c4s4
		5	t8s4
	3	1	p7s4
		2	p3s4
		3	pzs4
		4	p4s4
		5	p8s4
2	1	1	f7s5
		2	f3s5
		3	fzs5
		4	f4s5
		5	F8s5

NB!

Later you can check if data input is correct looking at the output of SPSS “within-subject factors”.

Choose a model and Sum of Squares type

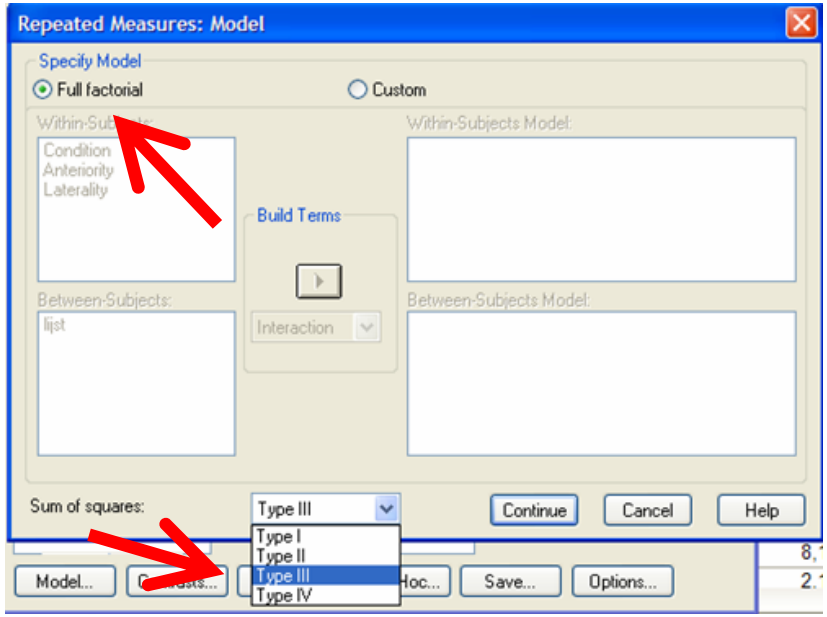
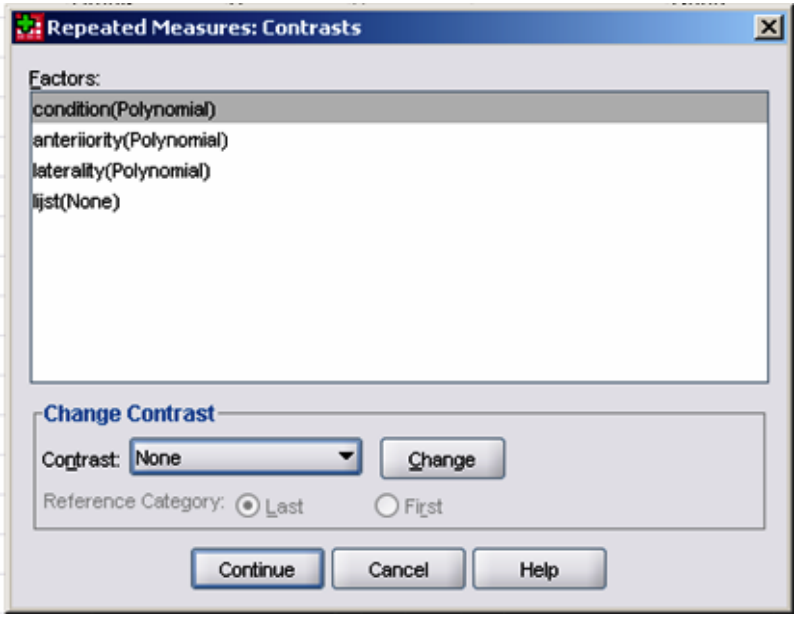


Table 7.11. The use of different regression approaches in analysis of variance

Type of *SS*	Use
Type I	The sources of variance are added sequentially: Each term is only adjusted for the term that precedes it in the model, in SPSS syntax it is used for nested models.
Type II	Used for any model that has main effects only.
Type III	Default in SPSS; any design with no empty cells.
Type IV	Used for situations with missing cells.

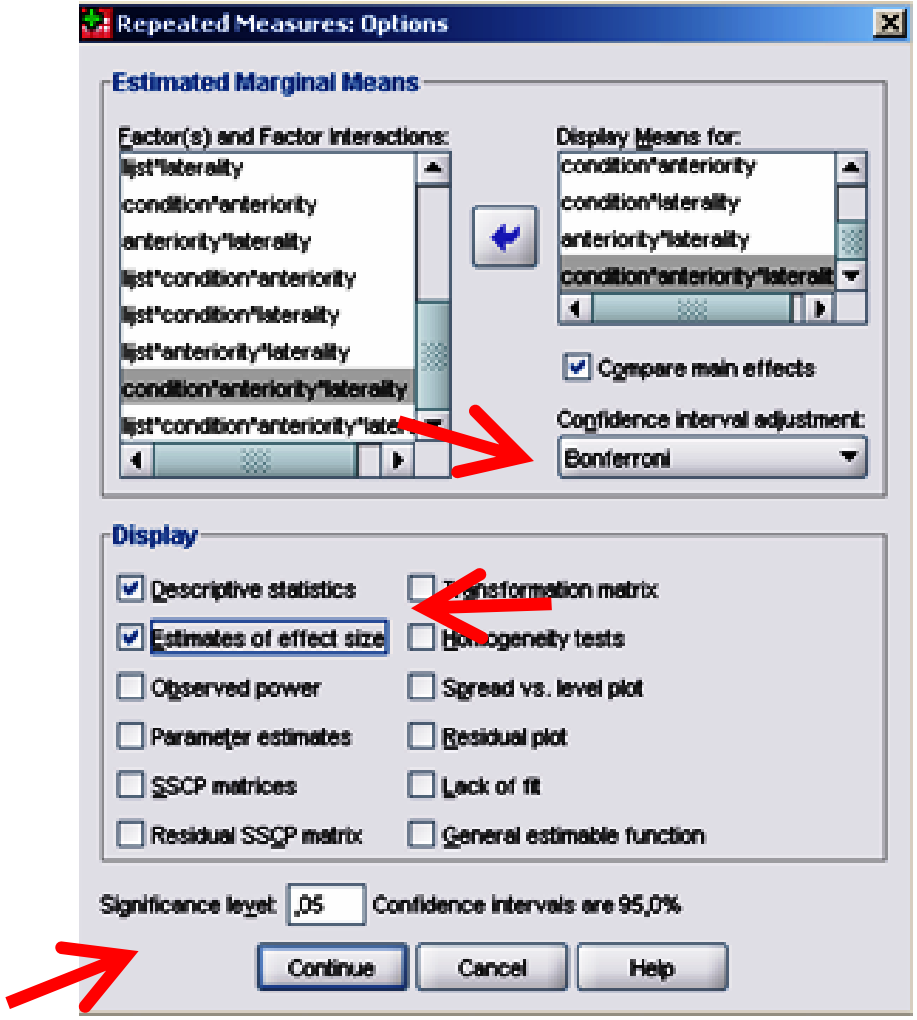
Choose contrast



- Polynomial

  None, Deviation, Simple, Difference, Helmert, Repeated, Polynomial

Post hoc tests, significance level



- Look for interactions
- Set significance level at .05 by default
- Check **Descriptive statistics** to get: observed means, standard deviations, and counts for all of the dependent variables in all cells; the Levene test for homogeneity of variance; Box's M; and Mauchly's test of sphericity.
- Check Estimates of effect size to get Partial Eta squared.

Sphericity Assumption

- The effect of violating sphericity is a loss of power (i.e. an increased probability of Type II error) and a test statistic (F-ratio) that simply cannot be compared to tabulated values of the F-distribution.
- For small sample sizes, this test is not very powerful. For large sample sizes, the test may be significant even when the impact of the departure on the results is small.
- If the the sphericity assumption appears to be violated, an adjustment to the numerator and denominator degrees of freedom can be made in order to validate the univariate F statistic.

Mauchly's test

- If Mauchly's test statistic is significant we conclude that there are significant differences between the variance of difference: the condition of sphericity has not been met.
- If Mauchly's test statistic is nonsignificant then it is reasonable to conclude that the variances of differences are not significantly different, they are roughly equal.
- If Mauchly's test is significant then we cannot trust the F-ratios produced by SPSS.

Correcting for Violations of Sphericity

- All of the corrections involve adjusting the degrees of freedom associated with the F-value.
- In all cases degrees of freedom are reduced based on an estimate of how ‘spherical’ the data are; by reducing the degrees of freedom we make the F-ratio more conservative (it has to be bigger to be deemed significant).

Possible corrections

- 1. Greenhouse and Geisser's (1958)
- 2. Huynh and Feldt's (1976)
- 3. The Lower Bound estimate.

$$\varepsilon_{GG} = \frac{(\text{trace}(\mathbf{S}_E))^2}{d \times \text{trace}(\mathbf{S}_E^2)}$$

$$\varepsilon_{HF} = \min\left(\frac{nd\varepsilon_{GG} - 2}{d(n - r_X) - d^2\varepsilon_{GG}}, 1\right)$$

$$\varepsilon_{LB} = 1/d$$

- Which correction to use?

- Look at the estimates of sphericity (ε) in the SPSS.
- When ε > 0.75 then use the Huynh-Feldt correction.
- When ε < 0.75, or nothing is known about sphericity at all, then use the Greenhouse-Geisser correction.

For all corrections the adjusted significance level is:

$$1 - \text{CDF.F}\left(F, \varepsilon d_{r_L}, \varepsilon d(n - r_X)\right)$$

Mauchly's Test of Sphericity[b]

Measure:MEASURE_1							
Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[a]		
					Greenhouse-Geisser	Huynh-Feldt	Lower-bound
condition	1,000	,000	0	.	1,000	1,000	1,000
anteriority	,321	15,920	2	,000	,596	,704	,500
laterality	,034	45,509	9	,000	,503	,659	,250
condition * anteriority	,380	13,561	2	,001	,617	,734	,500
condition * laterality	,069	35,928	9	,000	,540	,718	,250
anteriority * laterality	,004	67,556	35	,001	,391	,572	,125
condition * anteriority * laterality	,005	65,017	35	,002	,502	,799	,125

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 + lijst
Within Subjects Design: condition + anteriority + laterality + condition * anteriority + condition * laterality + anteriority * laterality + condition * anteriority * laterality

Differences in degrees of freedom

Tests of Within-Subjects Effects

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
condition * anteriority * laterality	Sphericity Assumed	13,975	8	1,747	2,126	,038	,124
	Greenhouse-Geisser	13,975	4,012	3,483	2,126	,088	,124
	Huynh-Feldt	13,975	6,390	2,187	2,126	,053	,124
	Lower-bound	13,975	1,000	13,975	2,126	,165	,124

Main electrodes

```
GLM f7s4 f3s4 fzs4 f4s4 f8s4 t7s4 c3s4 czs4 c4s4 t8s4 p7s4 p3s4 pzs4 p4s4 p8s4 f7s5
    f3s5 fzs5 f4s5 f8s5 t7s5 c3s5 czs5 c4s5 t8s5 p7s
  5 p3s5 pzs5 p4s5 p8s5 BY lijst
 /WSFACTOR=condition 2 Polynomial anteriority 3 Polynomial laterality 5 Polynomial
 /METHOD=SSTYPE(3)
 /EMMEANS=TABLES(condition) COMPARE
 /EMMEANS=TABLES(anteriority) COMPARE
/EMMEANS=TABLES(laterality) COMPARE
/EMMEANS=TABLES(condition*anteriority)
 /EMMEANS=TABLES(condition*laterality)
 /EMMEANS=TABLES(anteriority*laterality)
 /EMMEANS=TABLES(condition*anteriority*laterality)
 /PRINT=DESCRIPTIVE ETASQ
 /CRITERIA=ALPHA(.05)
 /WSDESIGN=condition anteriority laterality condition*anteriority condition*laterality
    anteriority*laterality condition*anteriority
  *laterality
 /DESIGN=lijst.
```

Prefrontal and Occipital electrodes

```
GLM
  fp1s4 afzs4 fp2s4 fp1s5 afzs5
    fp2s5 by lijst
 /WSFACTOR = cond 2
    Polynomial lat 3 Polynomial
 /METHOD = SSTYPE(3)
 /EMMEANS = TABLES(cond)
 /EMMEANS = TABLES(lat)
 /EMMEANS = TABLES(cond*lat)
 /PRINT = DESCRIPTIVE
 /CRITERIA = ALPHA(.05)
 /WSDESIGN = .
```

```
GLM
  o1s4 o2s4 o1s5 o2s5 by lijst
 /WSFACTOR = cond 2
    Polynomial lat 2 Polynomial
 /METHOD = SSTYPE(3)
 /EMMEANS = TABLES(cond)
 /EMMEANS = TABLES(lat)
 /EMMEANS = TABLES(cond*lat)
 /PRINT = DESCRIPTIVE
 /CRITERIA = ALPHA(.05)
 /WSDESIGN = .
```

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Condition	Pillai's Trace	,002	,024[a]	1,000	15,000	,878	,002
	Wilks' Lambda	,998	,024[a]	1,000	15,000	,878	,002
	Hotelling's Trace	,002	,024[a]	1,000	15,000	,878	,002
	Roy's Largest Root	,002	,024[a]	1,000	15,000	,878	,002
condition * lijst	Pillai's Trace	,026	,204[a]	2,000	15,000	,818	,026
	Wilks' Lambda	,974	,204[a]	2,000	15,000	,818	,026
	Hotelling's Trace	,027	,204[a]	2,000	15,000	,818	,026
	Roy's Largest Root	,027	,204[a]	2,000	15,000	,818	,026
Anteriority	Pillai's Trace	,545	8,370[a]	2,000	14,000	,004	,545
	Wilks' Lambda	,455	8,370[a]	2,000	14,000	,004	,545
	Hotelling's Trace	1,196	8,370[a]	2,000	14,000	,004	,545
	Roy's Largest Root	1,196	8,370[a]	2,000	14,000	,004	,545
condition * anteriority	Pillai's Trace	,356	3,873[a]	2,000	14,000	,046	,356
	Wilks' Lambda	,644	3,873[a]	2,000	14,000	,046	,356
	Hotelling's Trace	,553	3,873[a]	2,000	14,000	,046	,356
	Roy's Largest Root	,553	3,873[a]	2,000	14,000	,046	,356
anteriority * laterality	Pillai's Trace	,918	11,245[a]	8,000	8,000	,001	,918
	Wilks' Lambda	,082	11,245[a]	8,000	8,000	,001	,918
	Hotelling's Trace	11,245	11,245[a]	8,000	8,000	,001	,918
	Roy's Largest Root	11,245	11,245[a]	8,000	8,000	,001	,918
condition * anteriority * laterality	Pillai's Trace	,550	1,223[a]	8,000	8,000	,391	,550
	Wilks' Lambda	,450	1,223[a]	8,000	8,000	,391	,550
	Hotelling's Trace	1,223	1,223[a]	8,000	8,000	,391	,550
	Roy's Largest Root	1,223	1,223[a]	8,000	8,000	,391	,550

Early Bipolar Effect (180-320 ms post-onset: ELAN time-window)

- Main electrodes:

The main effect of *Violation* and the interaction of *Violation* x *Laterality* not significant (F-*values*<1).

The interaction of *Violation* x *Anteriority* significant (F(2,30)=5.34; p<.05), but qualified by a significant three-way interaction of *Violation* x *Anteriority* x *Laterality* (*F*(8,120)=2.22; *p*<.05).

Follow-up analyses showed (marginally) significant interactions between *Violation* x *Anteriority* for every level of *Laterality*, except for the electrodes on the far right (far left: F(2,30)=3.20; p=.07; left: F(2,30)=7.36; p<.01; middle: F(2,30)=8.72; p<.01; right: F(2,30)=3.18; p=.07; far right: F<1).

- Occipital electrodes:

A significant main effect of Violation (F(1,15)=5.35; p<.01), where the violation condition was more positive than the neutral condition (a difference of 0.8 μV);

- Prefrontal electrodes:

There were no significant effects in the analysis of the prefrontal electrodes.

Effect Sizes (violation *minus* neutral, in μV) for frontal, central, and posterior electrodes on every level of Laterality in the ELAN time-window (180-320 ms post-onset)

	Far left	**Left**	**Middle**	**Right**	**Far Right**
Frontal	**-0.8**	**-0.7**	**-0.9**	**-0.5**	**-0.4**
Central	**0.0**	**0.4**	**0.5**	**0.2**	**0.2**
Posterior	**0.9**	**1.1**	**1.2**	**0.6**	**0.1**

Positivity (350-550 ms post-onset: N400 Time-Window)

- Main electrodes:

Significant effect of Violation ($F(1,15)=5.95$; $p<.05$), with a larger positivity for the violation condition as compared to the neutral condition (a difference of 1.3 μV).

There was no interaction with topographical factors Anteriority and Laterality (all F-values<1).

- Occipital electrodes:

Only a main effect of Violation (a difference of 1.8 μV; $F(1,15)=7.61$; $p<.05$). T

- Prefrontal electrodes:

There were no significant effects in the analysis of the occipital electrodes (all p-values>.19).

Late Positivity (550-750 ms post-onset: P600 Time-Window)

- Main electrodes:

A significant main effect of Violation ($F(1,15)=7.99$; $p<.05$), with a larger positivity for the violation condition versus the neutral condition (a difference of 1.9 μV).

There was no interaction with Anteriority ($F<1$); the interaction with Laterality was marginally significant (($F(4,60)=2.22$; $p=.10$). These effects were qualified by a significant three-way interaction of Violation x Anteriority x Laterality ($F(8,120)=7.61$; $p<.05$). This interaction ensued from the effect of Violation (violation more positive than neutral) being quite pronounced on the left side of the scalp, and significantly less strong on the right (and even absent on far right electrodes). See Table 2 for the effectsizes on all electrodes contained in the main set.

Effect Sizes (violation *minus* neutral, in μV) for frontal, central, and posterior electrodes on every level of Laterality in the P600 time-window (550-750 ms post-onset)

	Far left	**Left**	**Middle**	**Right**	**Far Right**
Frontal	**2.1**	**3.2**	**2.6**	**2.3**	**1.1**
Central	**2.3**	**2.1**	**1.2**	**1.4**	**1.3**
Posterior	**2.3**	**2.7**	**1.9**	**1.3**	**0.5**

- Occipital electrodes:

The violation condition gave rise to a positivity on the left (O1: 0.5 μV), but to a slight negativity on the right (O2: -0.2 μV); this interaction was marginally significant ($F(1,15)=3.64$; $p=.08$).

- Prefrontal electrodes:

A main effect of Violation where the violation condition was much more positive than the neutral (a difference of 2.8 μV; $F(1,15)=11.65$; $p<.005$).

Conclusion

- According to Grice, all language users work from the default assumptions that their conversational partners are rational beings, who produce utterances that are true, clear, and relevant, and that do not contain more, but certainly not less information than is required by the specific conversational setting in which they occur.
- Violations of the Maxim of Quantity is detected within 200 ms, and leads to thematic and syntactic reanalysis, motivated by the desire to create a coherent representation of what is said.

Data

- Pragmatic Brainwaves: How the Brain Responds to Violations of the Gricean Maxim of Quantity.
- by John C. J. Hoeks

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