# Using Repeated Measures Analysis of Variance (RM-ANOVA) to Analyse Event-Related Potential Data

Harwintha Y. Anjarningsih

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# Outline:

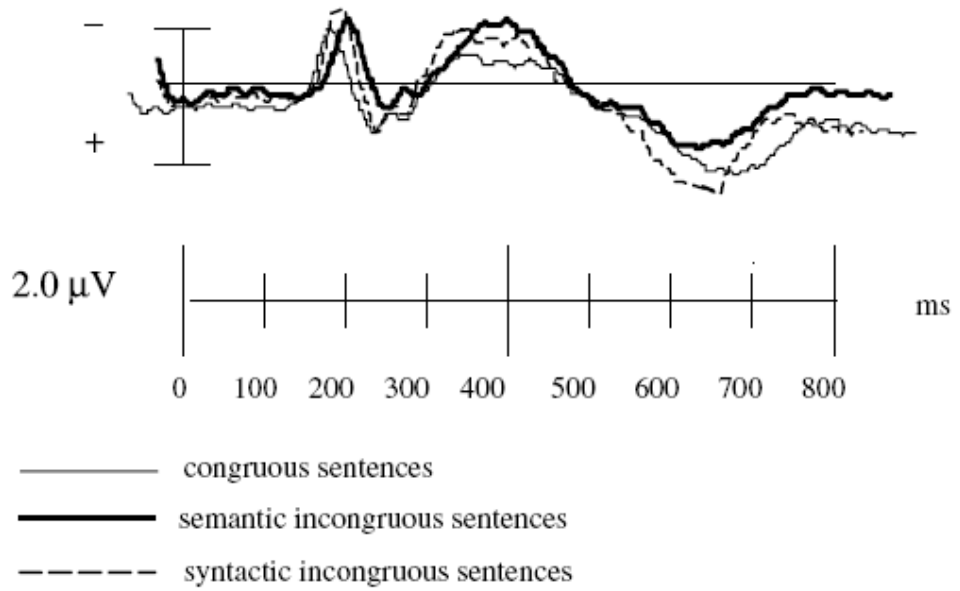
- What is ERP?
- The example experiment
- Why is RM-ANOVA used?
- Important issues in RM-ANOVA
- Results of the experiment
- My own future experiment

# What is ERP?

**He often eats dinner with his bicycle.**

**He often eats dinner with his family.**

# The brain's electrical activity that results from specific sensory, cognitive, or motor events




Grand-average ERPs elicited by the congruous, semantic and syntactic incongruous sentences with visual stimuli.

# The example experiment

- An EMCL thesis by Hua Dong
- Just the P600 part (syntactic violations)
- Stimuli:
- **HG**: De scheikundige begrijpt niets van de nieuwe weegschaal en **hij roept** zijn vrouw om hulp.
- **HU**: De scheikundige begrijpt niets van de nieuwe weegschaal en *__hij roep__ zijn vrouw om hulp.
- **LG**: Marnix is keihard met zijn neus op de tafel geklapt en **hij stelpt** de bloeding met een papieren zakdoek.
- **LU**: Marnix is keihard met zijn neus op de tafel geklapt en *__hij stelp__ de bloeding met een papieren zakdoek.

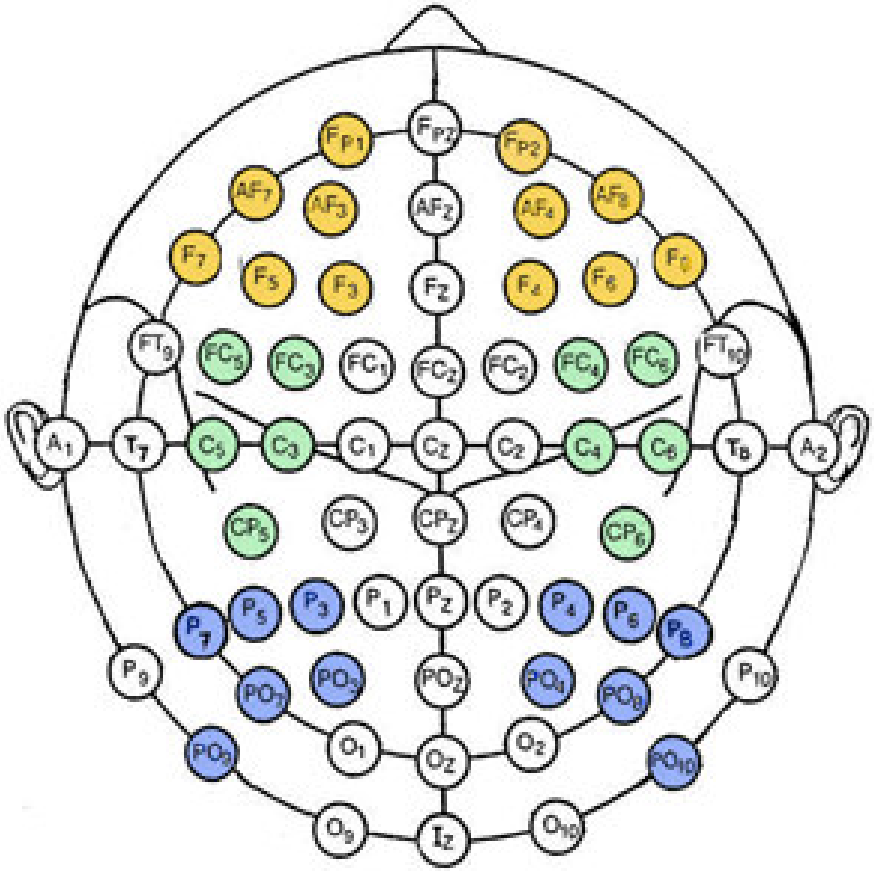
Independent variables (IV):

1. grammaticality
2. frequency
3. lateralization (left or right)
4. electrode position (anterior, middle, or posterior)

2 X 2 X 2 X 3

Dependent variable: amplitude of ERP component in the 500-700 ms window

# Electrode position and lateralization ROIs



Participants : 36 college students

native speakers of Dutch
right handed without any history of neurological trauma, language disorders, or alcohol abuse

Materials:

- 160 verbs (80 H, 80 L)
- Put in the second clause in compound sentences

# Why is RM-ANOVA used?

- Within-subject or repeated measures design
- Compare more than two independent variables with one dependent var.
- Avoid inflated error rates and hence greater power to detect effects

# Within-subject or repeated measures design

- The same people exposed to different experimental manipulations (HG, HU, LG, LU)
- Scores are not independent → cannot use between-group ANOVA → but check sphericity

# Compare more than two IVs with one DV

1. grammaticality
2. frequency
3. lateralization (left or right)
4. electrode position (anterior, middle, or posterior)

→ cannot use t-test or independent/ between-subject ANOVA

→ cannot use MANOVA

# Avoid inflated error rates

- Three groups to be compared using t-test→ 1 and 2, 1 and 3, and 2 and 3
- Each uses 0.05 level of significance → overall probability of no Type I error is 0.95 * 3 = 0.875 → probability of making at least one Type I error is 1 – (0.95 * 3) = 0.143 or 14.3 %

# Important issues in RM-ANOVA

- Sphericity
- Corrections

# Sphericity

- Equality of the variances of the differences between treatment levels ($\varepsilon$)

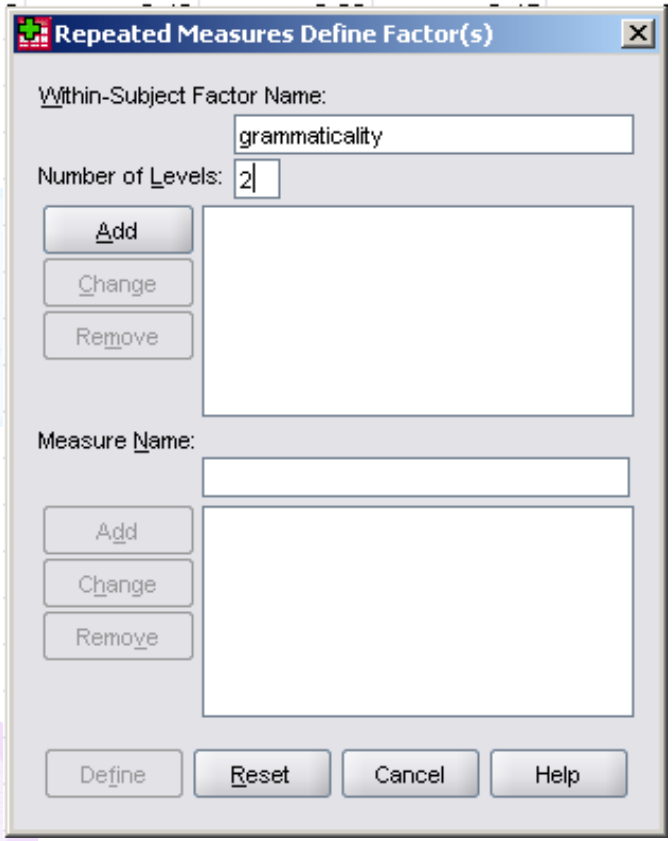
| Group A | Group B | Group C | A-B | A-C | B-C |
|---|---|---|---|---|---|
| 9 | 12 | 7 | -3 | 2 | 5 |
| 15 | 15 | 12 | 0 | 3 | 3 |
| 25 | 30 | 20 | -5 | 5 | 10 |
| 35 | 30 | 28 | 5 | 7 | 2 |
| 30 | 27 | 20 | 3 | 10 | 7 |
| | | Variance | 17.0 | 10.3 | 10.3 |

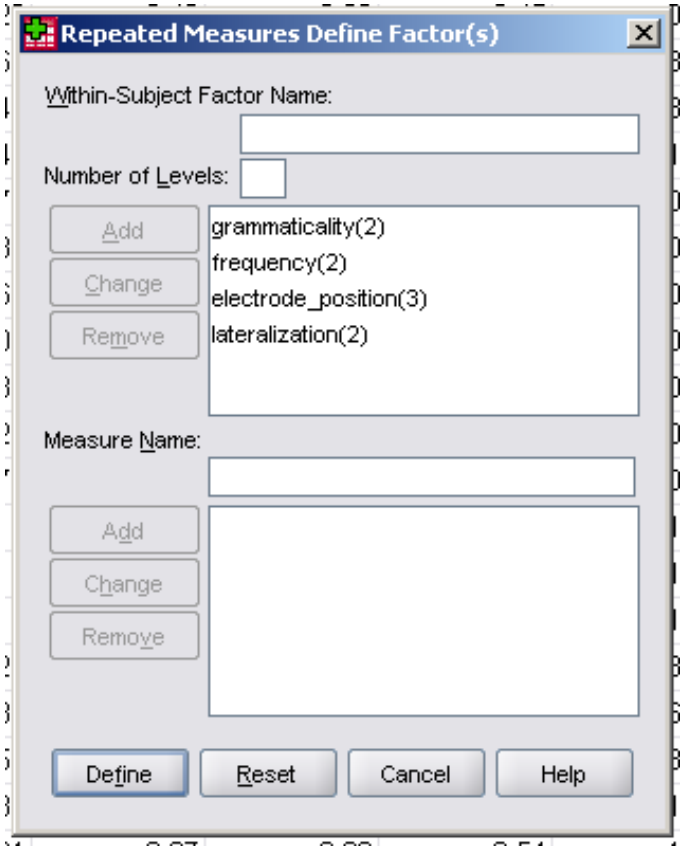
- In SPSS → check Mauchly's test → if test statistic is significant (e.g. 0.05) we need to do corrections

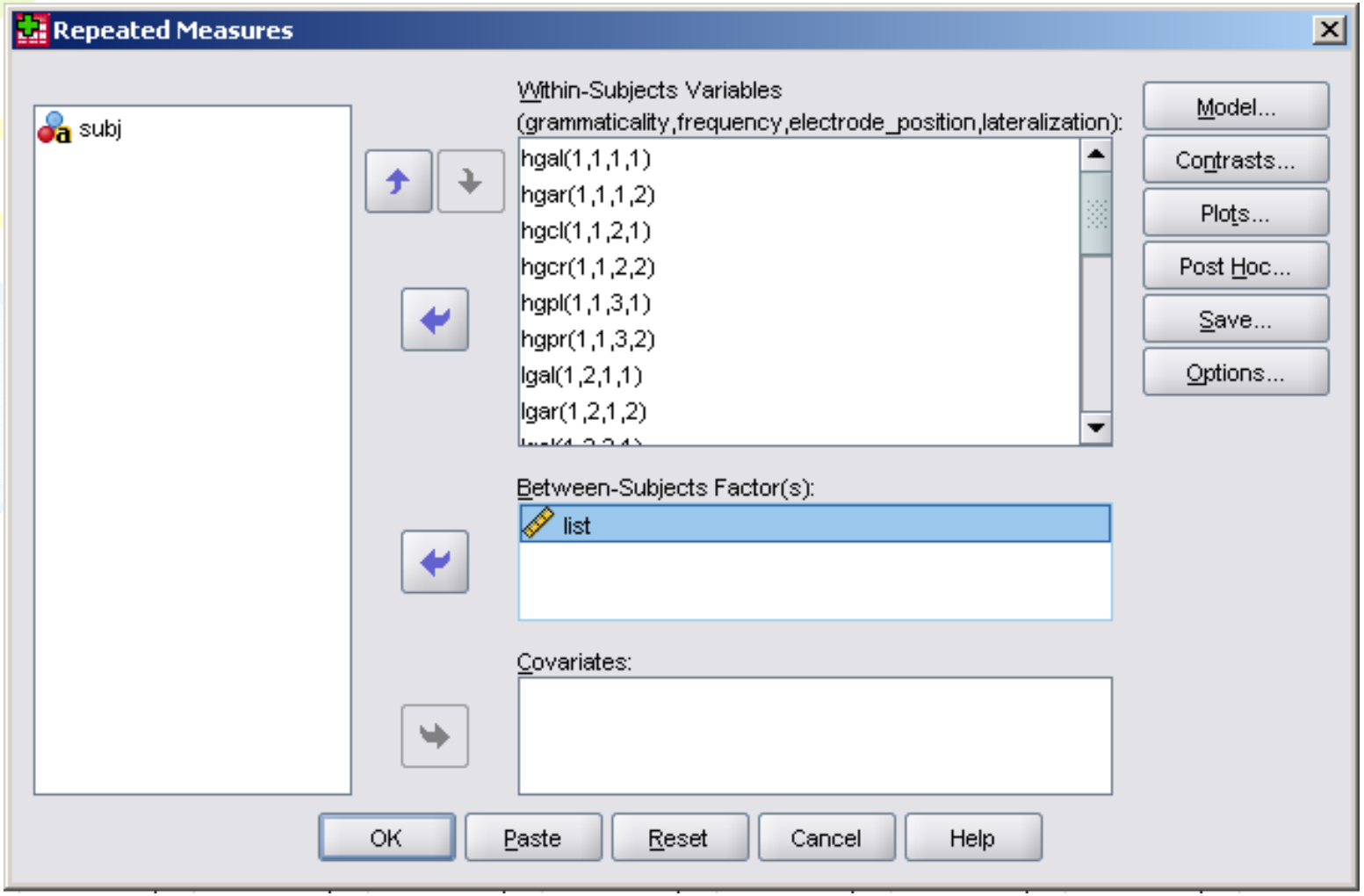
# Corrections

- Greenhouse-Geisser
- Huynh-Feldt

# Results of the experiment




Repeated Measures
subj
Within-Subjects Variables
(grammaticality,frequency,electrode_position,lateralization):
hgal(1,1,1,1)
hgar(1,1,1,2)
hgcl(1,1,2,1)
hgcr(1,1,2,2)
hgpl(1,1,3,1)
hgpr(1,1,3,2)
lgal(1,2,1,1)
lgar(1,2,1,2)
Between-Subjects Factor(s):
list
Covariates:
Model...
Contrasts...
Plots...
Post Hoc...
Save...
Options...
OK
Paste
Reset
Cancel
Help

**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 |
| grammaticality | 1,000 | ,000 | 0 | . | 1,000 | 1,000 | 1,000 |
| frequency | 1,000 | ,000 | 0 | . | 1,000 | 1,000 | 1,000 |
| electrode_position | ,309 | 36,415 | 2 | ,000 | ,591 | ,658 | ,500 |
| lateralization | 1,000 | ,000 | 0 | . | 1,000 | 1,000 | 1,000 |
| grammaticality * frequency | 1,000 | ,000 | 0 | . | 1,000 | 1,000 | 1,000 |
| grammaticality * electrode_position | ,340 | 33,434 | 2 | ,000 | ,602 | ,672 | ,500 |
| frequency * electrode_position | ,440 | 25,485 | 2 | ,000 | ,641 | ,718 | ,500 |
| grammaticality * frequency * electrode_position | ,262 | 41,479 | 2 | ,000 | ,575 | ,639 | ,500 |
| grammaticality * lateralization | 1,000 | ,000 | 0 | . | 1,000 | 1,000 | 1,000 |
| frequency * lateralization | 1,000 | ,000 | 0 | . | 1,000 | 1,000 | 1,000 |
| grammaticality * frequency * lateralization | 1,000 | ,000 | 0 | . | 1,000 | 1,000 | 1,000 |
| electrode_position * lateralization | ,803 | 6,785 | 2 | ,034 | ,836 | ,959 | ,500 |
| grammaticality * electrode_position * lateralization | ,755 | 8,703 | 2 | ,013 | ,803 | ,919 | ,500 |
| frequency * electrode_position * lateralization | ,846 | 5,197 | 2 | ,074 | ,866 | ,997 | ,500 |
| grammaticality * frequency * electrode_position * lateralization | ,938 | 1,972 | 2 | ,373 | ,942 | 1,000 | ,500 |

- Main effect of grammaticality (p=.000, partial $\eta^2$.367)
- Main effect of lateralization (p=.012, partial $\eta^2$ 0.183)
- Marginal main effect of electrode position (p=.058 GG, .052 HF, partial $\eta^2$=.102)
- Interaction between grammaticality and electrode position (p=.000, partial $\eta^2$ .526)
- Interaction between grammaticality and lateralization (p=.000, partial $\eta^2$ .435)

# Main effect of grammaticality

**Estimates**

Measure:MEASURE_1

| grammaticality | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| 1 | ,766 | ,190 | ,380 | 1,152 |
| 2 | 1,519 | ,184 | 1,143 | 1,895 |

**Pairwise Comparisons**

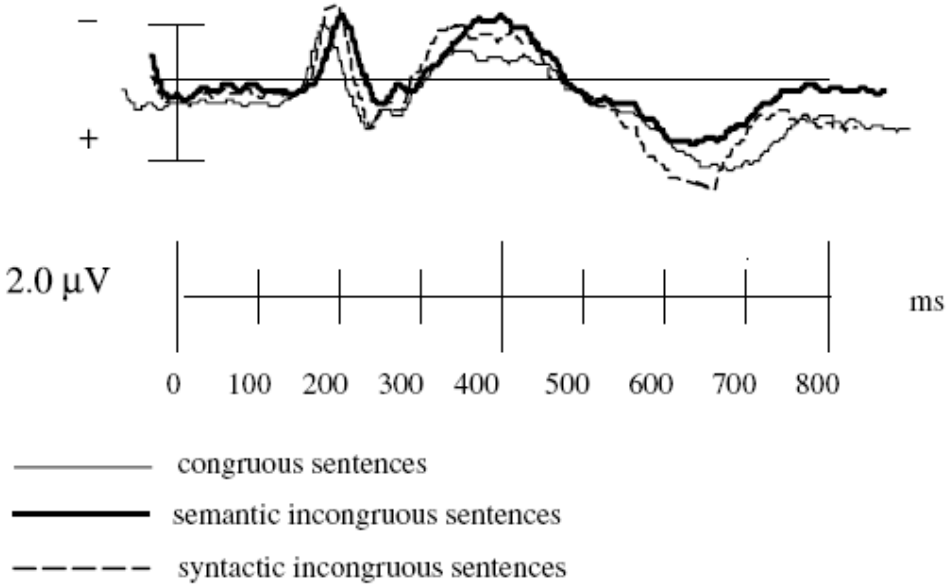
Measure:MEASURE_1

| (I) grammaticality | (J) grammaticality | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 2 | -,753* | ,175 | ,000 | -1,109 | -,397 |
| 2 | 1 | ,753* | ,175 | ,000 | ,397 | 1,109 |

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Bonferroni.




Grand-average ERPs elicited by the congruous, semantic and syntactic incongruous sentences with visual stimuli.

# Main effect of lateralization

**Estimates**

Measure:MEASURE_1

| later alizat ion | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| 1 | 1,011 | ,168 | ,669 | 1,353 |
| 2 | 1,274 | ,177 | ,913 | 1,634 |

**Pairwise Comparisons**

Measure:MEASURE_1

| (I) later alizat ion | (J) later alizat ion | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 2 | -,263* | ,098 | ,012 | -,463 | -,063 |
| 2 | 1 | ,263* | ,098 | ,012 | ,063 | ,463 |

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Bonferroni.

# Marginal main effect of electrode position

**Estimates**

Measure:MEASURE_1

| electrode_po... | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| 1 | ,923 | ,253 | ,407 | 1,438 |
| 2 | 1,571 | ,197 | 1,171 | 1,972 |
| 3 | ,933 | ,235 | ,454 | 1,412 |

**Pairwise Comparisons**

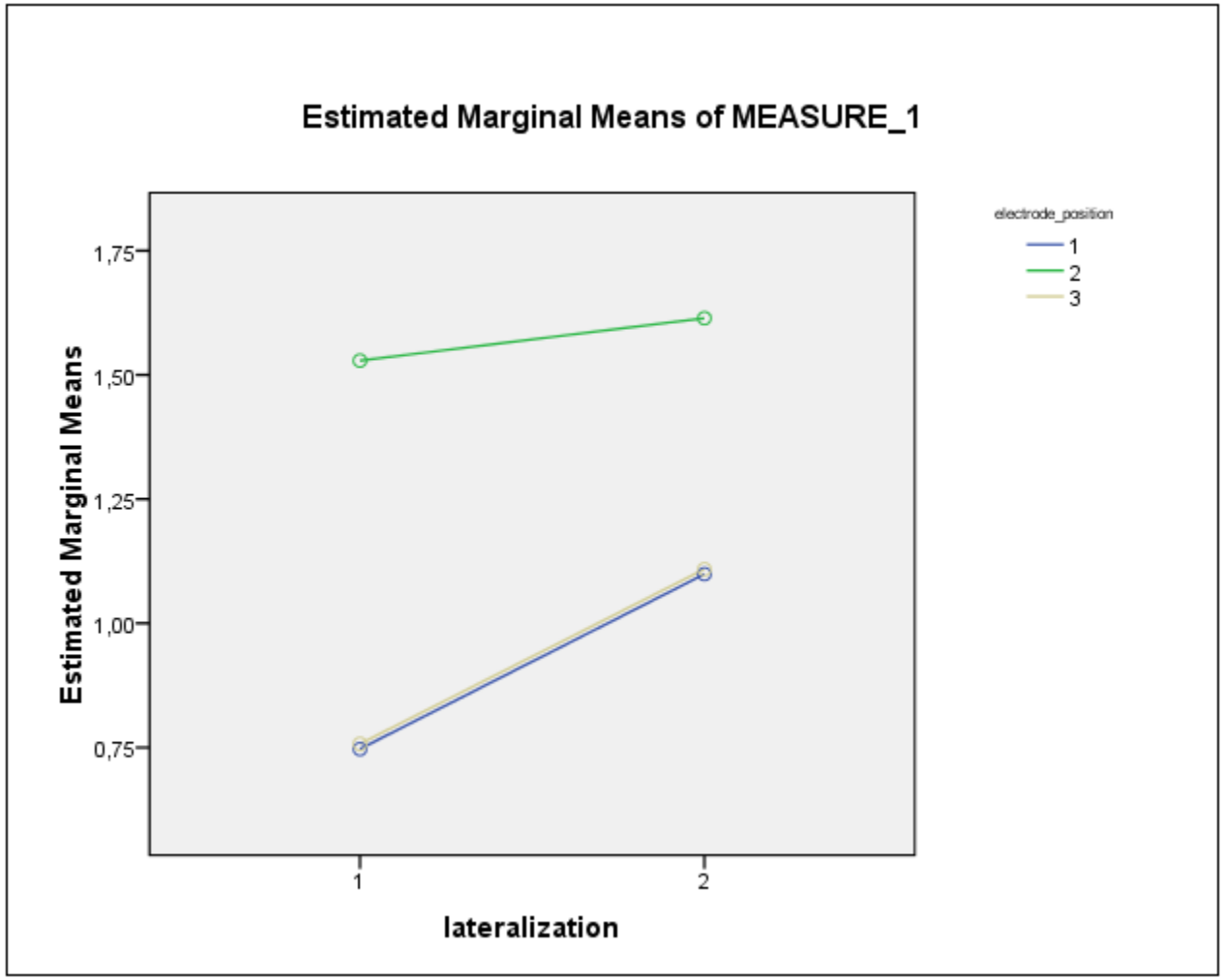
Measure:MEASURE_1

| (I) electrode_position | (J) electrode_position | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 2 | -,648* | ,194 | ,006 | -1,139 | -,158 |
| | 3 | -,010 | ,372 | 1,000 | -,951 | ,930 |
| 2 | 1 | ,648* | ,194 | ,006 | ,158 | 1,139 |
| | 3 | ,638* | ,227 | ,025 | ,065 | 1,212 |
| 3 | 1 | ,010 | ,372 | 1,000 | -,930 | ,951 |
| | 2 | -,638* | ,227 | ,025 | -1,212 | -,065 |

Based on estimated marginal means

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

a. Adjustment for multiple comparisons: Bonferroni.


Estimated Marginal Means of MEASURE_1
Estimated Marginal Means
1,75
1,50
1,25
1,00
0,75
1
2
lateralization
electrode_position
1
2
3

# Conclusion of the example exp.

- Subject-verb violations in Dutch elicited the P600 component in the 500-700 ms. window.
- This seems to be independent of frequency of the verbs.
- The component is right-lateralized with more activation in the middle electrodes.

# My future experiment

- Time reference in Indonesian → temporal adverbs & aspectual adverbs
- Processing difference → semantic violations to lexical adverbs, syntactic violations to aspectual adverbs

Ayah saya sudah membaca koran.
Father my already read a newspaper.

Baru saja ayah saya membaca koran.
Just now father my read a newspaper.