MIXED DESIGN ANOVA
Analysis of ERP-data

Seminar in Methodology & Statistics

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Content

- Problem background
- Statistical analysis
- Results
- Discussion

BACKGROUND (I)

- Hypothesis:
  - Dyslexia is caused by a '**phonological deficit**'
    - Dyslectic children cannot discriminate between subtle phoneme differences (ba/da)
    - Alphabetic script is based on phonemes (grapheme-phoneme conversion)
- How can we test this?
    - Behavioral studies
    - **EEG-studies**

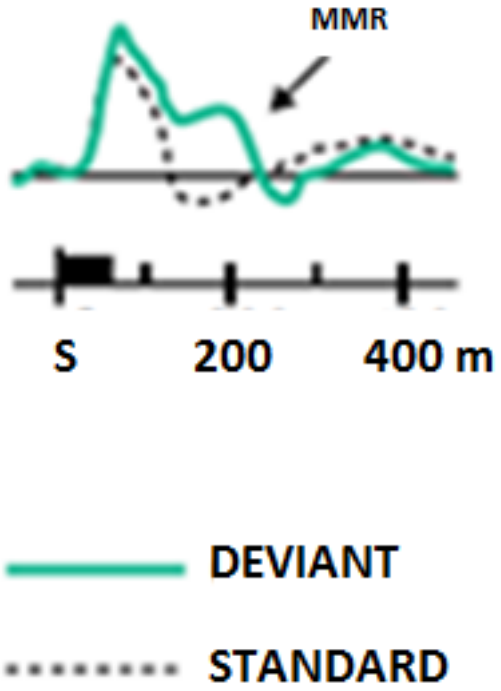
BACKGROUND (II)

- What is EEG?
  - Measure electrical activity in the brain

BACKGROUND (III)

- How can we use EEG to test the phonological deficit hypothesis?
  - MisMatch Response (**MMR**)
    - Oddball Paradigm

      babababababadababababababa
  - Prediction:
    - If dyslectics do not notice the deviant in the signal, they will **not** show a significant MMR



BACKGROUND (IV)

- Studies with dyslectic children & adults:
  - Dyslectics do indeed show a less significant MMR than the control group (Schulte-Körne, Deimel, Bartling en Remschmidt, 1998; 2001; Kraus, McGee, Carrell, Zecker, Nicol en Koch, 1996)

    → they cannot discriminate between phonemes

- Can the MisMatch Response also be used as a predictor for dyslexia?

BACKGROUND (V)

- Problem:
  - Dyslexia can only be diagnosed after a child has started to read and write
- Solution:
  - Follow children from babies until childhood
- Problem:
  - Only 4% of the population is diagnosed with dyslexia (Grigorenko, 2001)
- Solution:
  - **Familiar Risk for Dyslexia:**
    children with at least one parent and one other family member who are dyslectic have an increased risk (40-60%) to be dyslectic themselves (Gigorenko, 2001)

BACKGROUND (VI)

- Dutch Dyslexia Program:
  - EEG-measurements when children were 17-months old (oddball-paradigm)
  - Follow-up when children were in grade 4/5
  - Compare 17-months EEG between children who are diagnosed as dyslectic and children who are not dyslectic (control group)

BACKGROUND (VII)

- Research questions
  - Is there a significant difference between the EEG-response to standard /ba/ and deviant /da/ (MMR) for children who are diagnosed with dyslexia?
  - If there is a difference for the dyslectic group: is this difference between standard and deviant larger for the non-dyslectic group?
  - Is the EEG-response stronger in the left hemisphere than in the right hemisphere/midline?

BACKGROUND (VIII)

- Hypotheses & predictions:
  - Children who are diagnosed as dyslectic cannot discriminate between phonemes as well as their controls

  → they do not notice the difference between standard /ba/ and deviant /da/

  → they will show no MMR in the EEG-signal

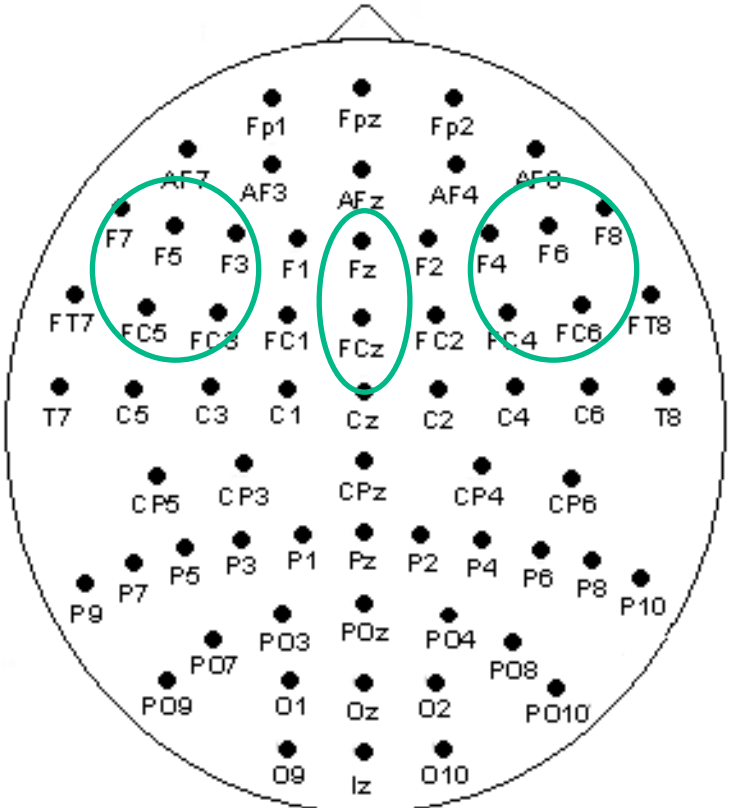
  OR

  → they do not notice the difference between /ba/ and /da/ as well as their control group

  → the peak in the signal that is caused by the deviant is less strong than for children who are not dyslectic

STATISTICAL ANALYSIS

- Dependent variable:
  - mean EEG-response between 200-260 milliseconds after stimulus onset
- Independent variables:
  - Diagnosis (Dyslexia/Control)
  - Stimulus (Standard/Deviant)
  - Location (Left-Middle-Right)



STATISTICAL ANALYSIS

		Left		**Midline**		**Right**	
		Standard	***Deviant***	***Standard***	***Deviant***	***Standard***	***Deviant***
Control	1						
	2						
(28)	3						
	…						
	28						
Dyslexia	28						
	29						
(17)	30						
	…						
	45						

STATISTICAL ANALYSIS

- Independent factors:
  - Between subjects
    - Diagnosis

Compare two groups

  - Within subjects
    - Stimulus
    - Location

More than one measurement for each participant!

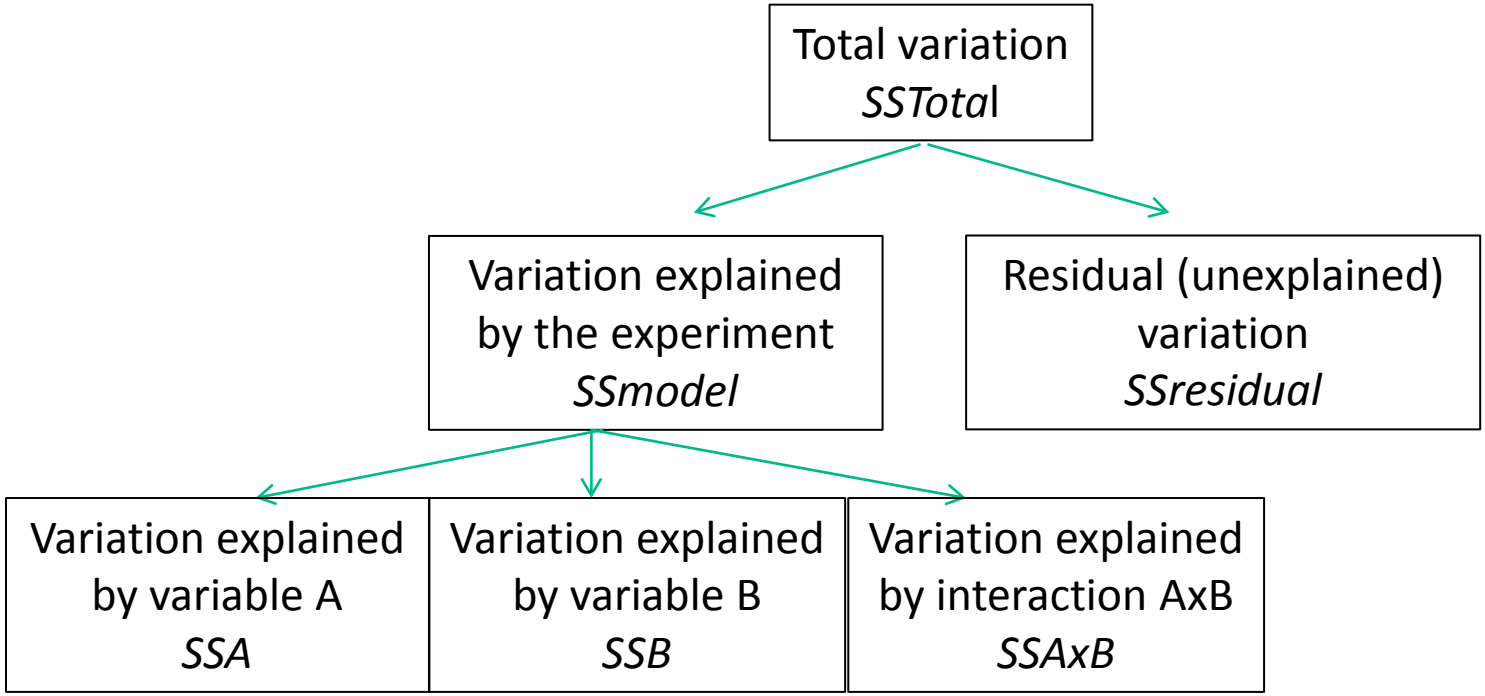
➔MIXED DESIGN ANOVA

MIXED DESIGN ANOVA

- Independent ANOVA:
  - Variation between subject groups
    (between subjects factor)
- Repeated Measures ANOVA:
  - Variation within one subject
    (within subjects factor)

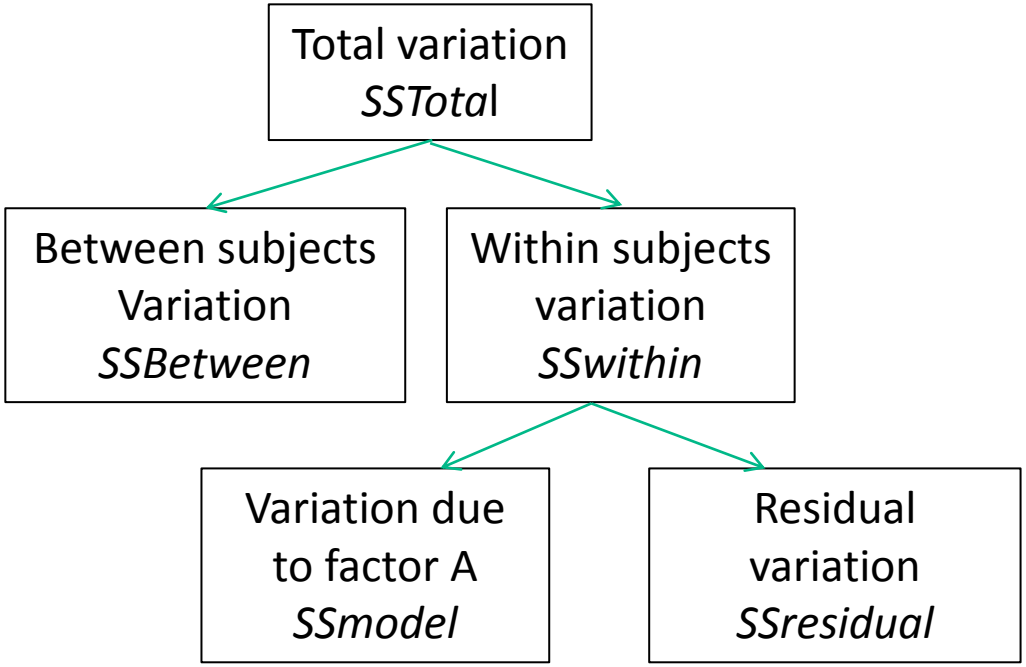
→ how much of this variability is due to the experimental manipulation, relative to random factors (residual)?

INDEPENDENT ANOVA



- F = Msmodel / Msresidual
- If more than one factor:
- $F_A = Ms_A / MS_r$
- $F_B = MS_B / MS_r$
- $F_{AxB} = MS_{AxB} / MS_r$

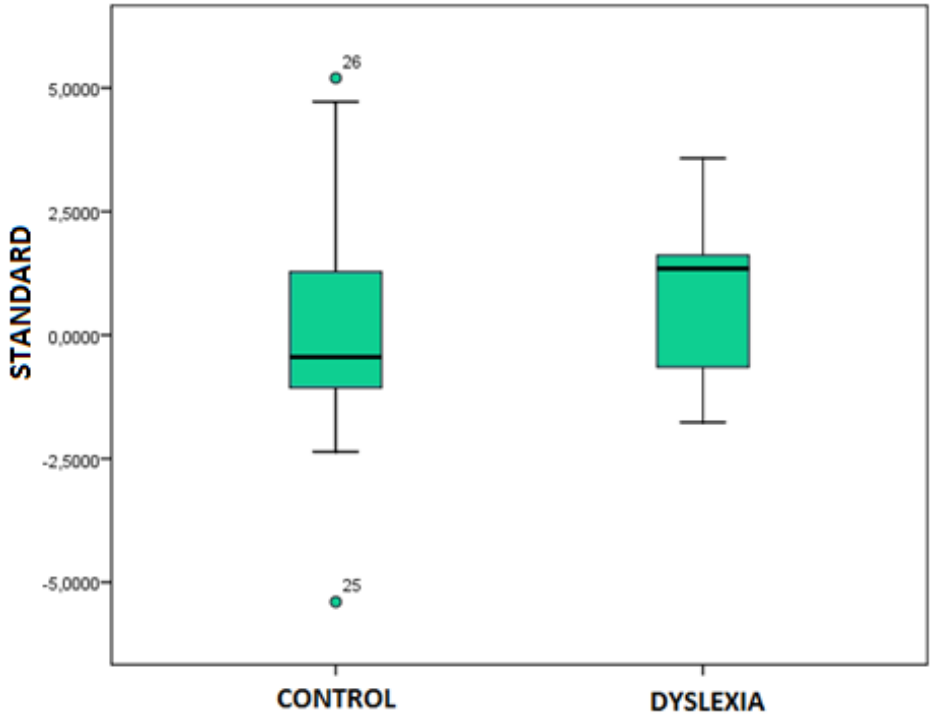
REPEATED MEASURES ANOVA

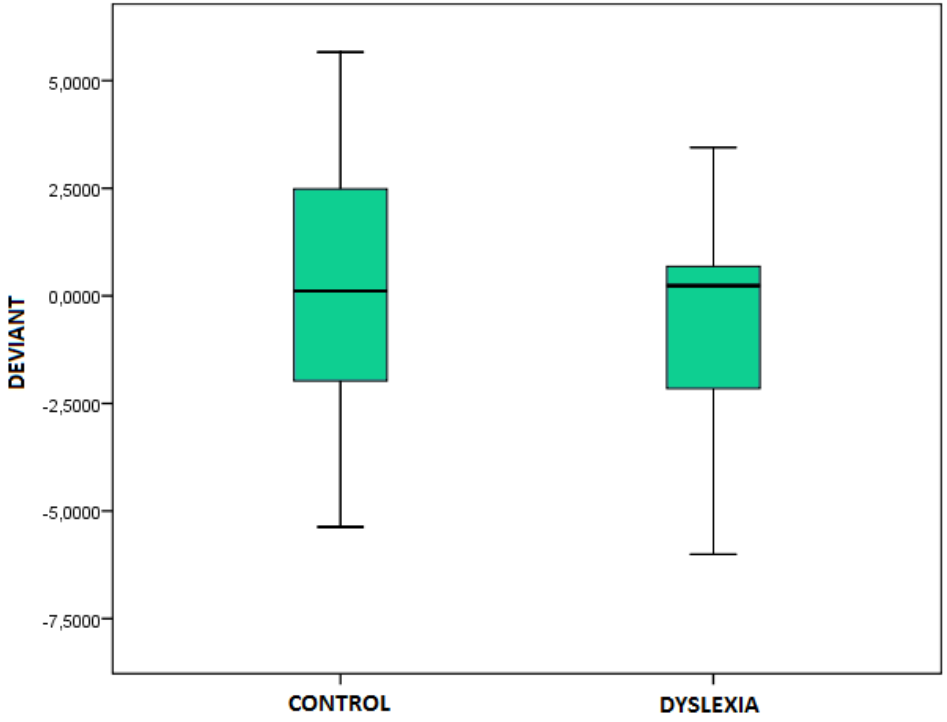


- F = MSmodel/MSresidual
- Variance due to differences between participants is isolated; resulting error (residual) is smaller → F-test for the treatment effect is more powerful

STATISTICAL ANALYSIS

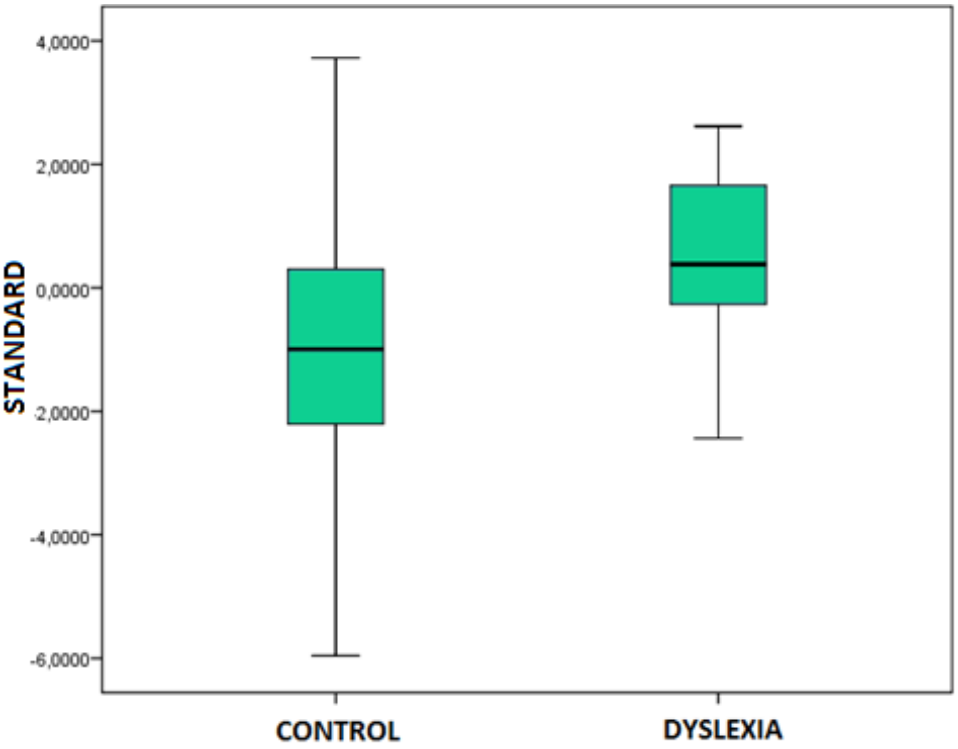
- LEFT HEMISPHERE

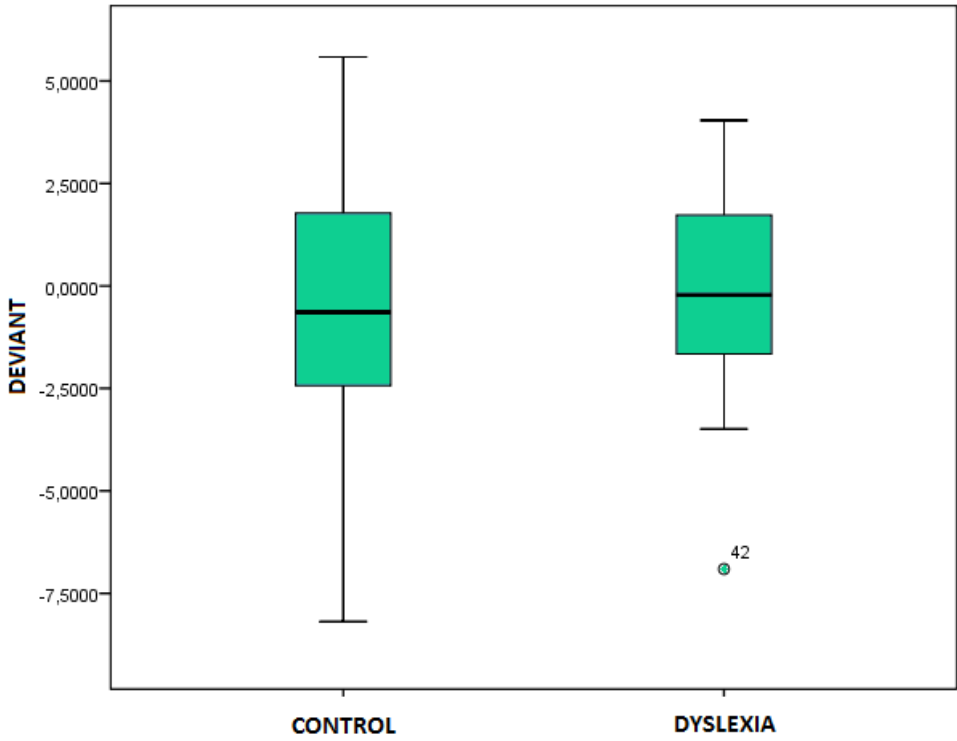




STATISTICAL ANALYSIS

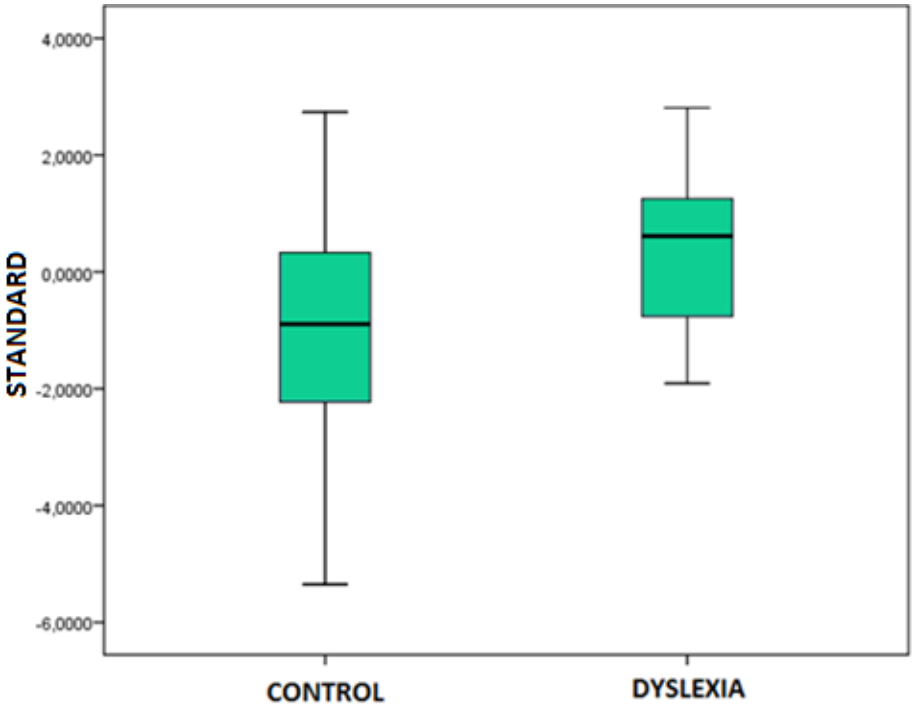
- MIDLINE

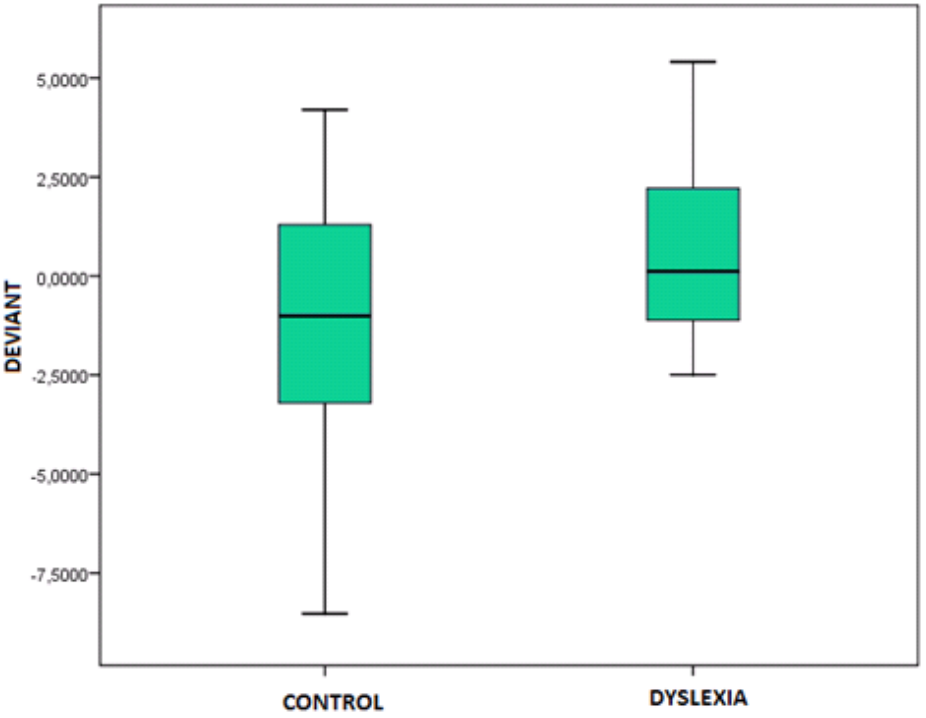




STATISTICAL ANALYSIS

- RIGHT HEMISPHERE





STATISTICAL ANALYSIS

- After inspection of outliers, these participants are removed.

		N
Diagnosis	NO DYSLEXIA	26
	DYSLEXIA	16

TESTING ASSUMPTIONS

- Assumption 1:
  - Scores in different conditions are independent
- Not true.
  - Scores are **not independent** (within subjects)

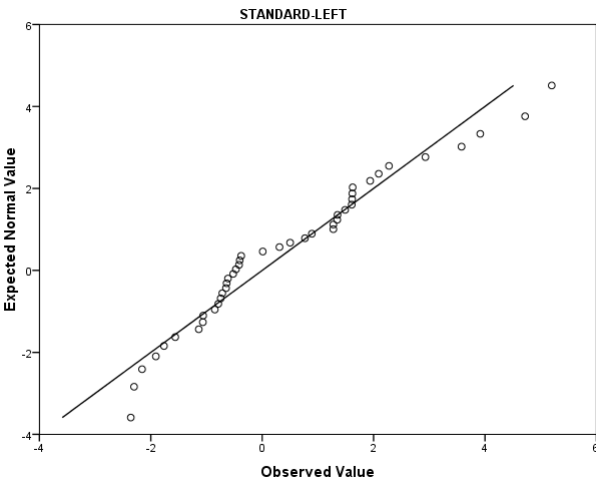
    → normal F-test will lack accuracy
- Repeated Measures ANOVA:
  - Within-participant variability (SSw)
    - Effect of experiment
    - Error

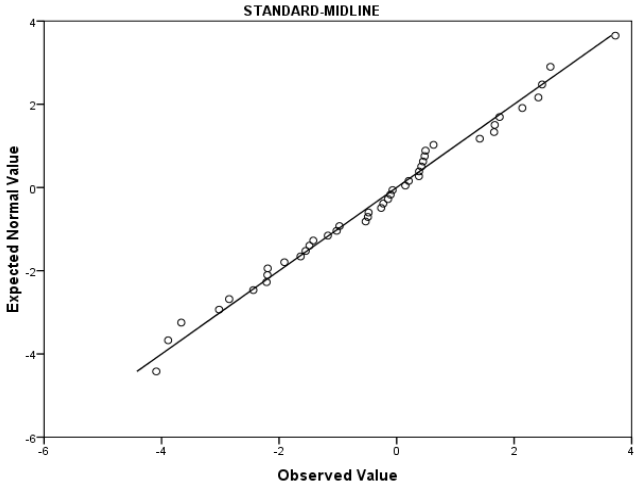
TESTING ASSUMPTIONS

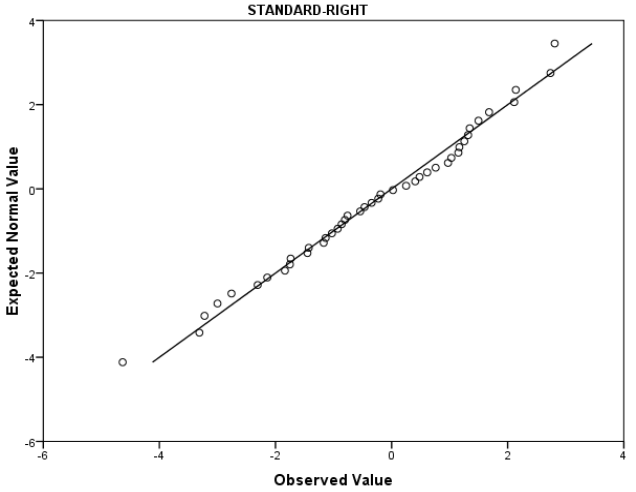
- Assumption 2:
  - Normal distribution in each subgroup

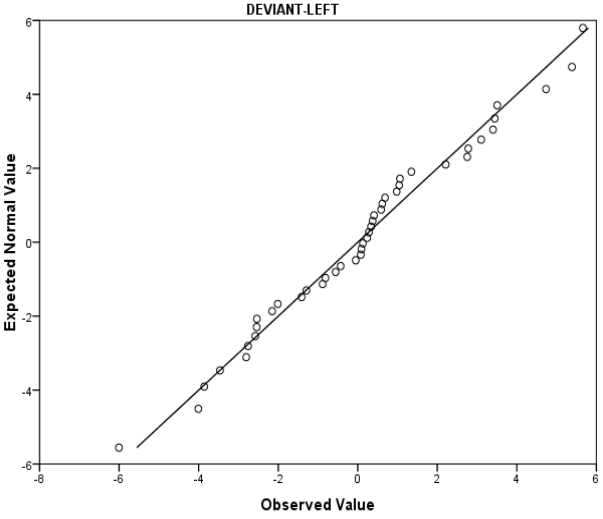
		Shapiro-Wilk	N	P
Standard – Right	Control	0.963	26	0.696
	Dyslexia	0.987	16	0.973
Standard – Left	Control	0.933	26	0.243
	Dyslexia	0.947	16	0.165
Standard – Midline	Control	0.963	26	0.693
	Dyslexia	0.995	16	0.996
Deviant – Right	Control	0.957	26	0.574
	Dyslexia	0.980	16	0.849
Deviant – Left	Control	0.929	26	0.206
	Dyslexia	0.980	16	0.843
Deviant – Midline	Control	0.948	26	0.432
	Dyslexia	0.976	16	0.754

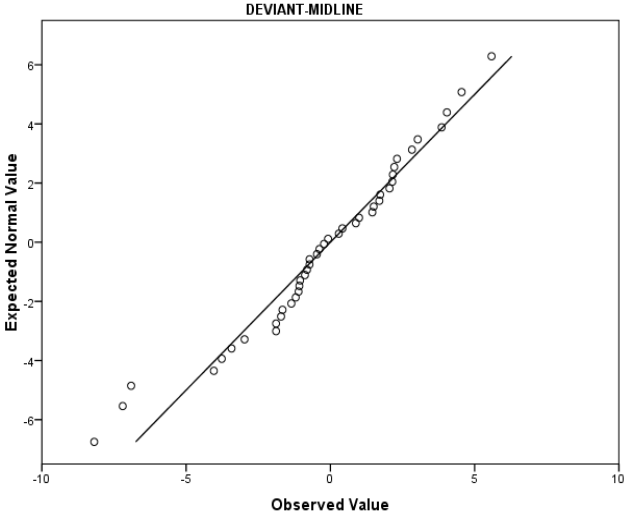
TESTING ASSUMPTIONS

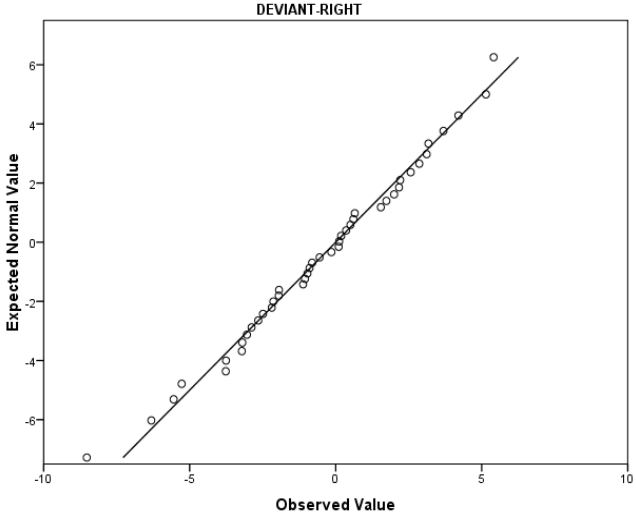












TESTING ASSUMPTIONS

- Assumption 3:
  - Homogeneity of variances
    - Smallest SD ≥ 0.5 x largest SD

HOMOGENEITY OF VARIANCES

		Mean	SD	N
Standard – Right	Control	-0.82	1.83	26
	Dyslexia	0.21	1.37	16
	Total	-0.43	1.73	42
Standard – Left	Control	0.06	1.81	26
	Dyslexia	0.74	1.56	16
	Total	0.32	1.74	42
Standard – Midline	Control	-0.73	1.96	26
	Dyslexia	0.26	1.36	16
	Total	-0.36	1.80	42
Deviant – Right	Control	-1.36	3.28	26
	Dyslexia	0.47	3.04	16
	Total	-0.66	3.28	42
Deviant – Left	Control	0.22	2.50	26
	Dyslexia	-0.37	2.42	16
	Total	0.00	2.46	42
Deviant – Midline	Control	-0.39	3.30	26
	Dyslexia	0.28	1.05	16
	Total	-0.13	2.88	42

HOMOGENEITY OF VARIANCES BETWEEN SUBJECTS FACTOR

- Levene's test

	F	Df1	Df2	P
Standard – Right	0.992	1	40	0.325
Standard – Left	0.131	1	40	0.719
Standard – Midline	2.432	1	40	0.127
Deviant – Right	0.648	1	40	0.425
Deviant – Left	0.040	1	40	0.843
Deviant – Midline	1.867	1	40	0.179

TESTING ASSUMPTIONS

- Assumption 4
  - **Sphericity** for the within-subjects factors
    the variances of the differences between the levels of the within-subjects-factor are equal
    - $\sigma^2_{(xi-xj)} \approx \sigma^2_{(xi-xk)} \approx \sigma^2_{(xj-xk)}$
    - Only for within subjects factors that have more than two levels
  - Less restrictive form of compound symmetry
    - Variances across conditions are equal
    - Covariance between pairs of conditions is equal
      (no two conditions are any more dependent than any other two)

SPHERICITY

Condition A	**Condition B**	**Condition C**	**A-B**	**A-C**	**B-C**
10	12	8	-2	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:	***15.7***	***10.3***	***10.3***

SPHERICITY

- Sphericity-test: Mauchly's W
  - Tests the hypothesis that the variances of the differences between conditions are equal
  - If significant → no sphericity of the data
    - Loss of power
    - F-ratio cannot be compared to the F-distribution

    → Correction is needed

SPHERICITY

- Correction is based on ε
  - The extent to which the data deviates from sphericity
    - Greenhouse-Geisser's
    - Huyn-Feldt
  - The closer ε is to its minimal value, the less 'spherical' the data are
    - $1/(k-1) \leq \varepsilon \leq 1$ (k = number of treatments)

SPHERICITY

- Correction of the degrees of freedom
  - Df1 = ε x (k-1)
  - Df2= ε x (k-1)(n-1)

  - Makes F more conservative; need larger F to become significant

SPHERICITY – MAUCHLY'S TEST

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon *Greenhouse -Geisser*	*Huynh -Feldt*	*Lower-bound*
stimulus	1,000	,000	0	.	1,00	1,00	1,00
location	,963	1,469	2	,48	,96	1,00	,50
stimulus * location	,917	3,368	2	,19	,92	,99	,50

Only 2 levels → always sphericity

Which one to choose?
Field:
- Greenhouse-Geisser if ε < 0.75)
- Huyn-Feldt if ε > 0.75 (less conservative)

STATISTICAL ANALYSIS

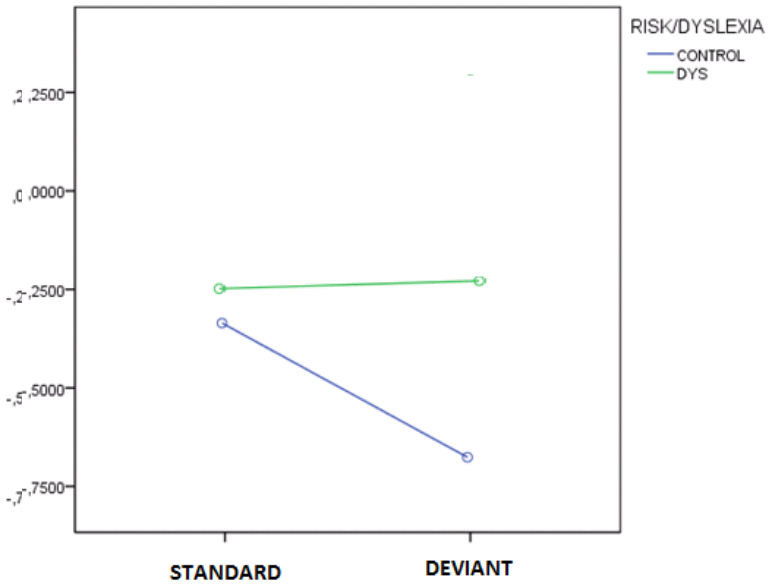
- Assumptions for mixed-design ANOVA:
  - Not- independent samples √
  - Normal distributions per subgroup √
  - Homogeneity of variances for the between-subjects factor √
  - Sphericity for the within-subjects factor √

➔ **PERFORM THE TEST**

STATISTICAL ANALYSIS

- What is expected:
  - Larger difference between reactions on standard/ deviant stimulus for non-dyslectic than for dyslectic children, which is more pronounced in the left hemisphere than in other locations in the brain
  - Interaction

    stimulus*diagnosis*location



RESULTS

- Between-subjects effects

	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	3,394	1	3,394	,190	,665	,005
Diagnosis	35,166	1	35,166	1,973	,168	,047
Error	713,106	40	17,828			

Type of SS
Type I

Type II
Type III
Type IV

P-value is not a direct reflection of the strength of the effect

→ How much of the total variation is explained by the factor under consideration?

$$\text{Partial } \eta^2 = \frac{SS_{factor}}{SS_{factor} + SS_{error}} = \frac{35.166}{35.166 + 713.106} = 0.047$$

> 0.5: large effect

RESULTS
WITHIN-SUBJECTS EFFECTS

		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
stimulus	Sphericity Assumed	1,234	1	1,234	,328	,570	,008
	Greenhouse-Geisser	1,234	1,000	1,234	,328	,570	,008
	Huynh-Feldt	1,234	1,000	1,234	,328	,570	,008
	Lower-bound	1,234	1,000	1,234	,328	,570	,008
stimulus * Diagnosis	Sphericity Assumed	1,049	1	1,049	,279	,600	,007
	Greenhouse-Geisser	1,049	1,000	1,049	,279	,600	,007
	Huynh-Feldt	1,049	1,000	1,049	,279	,600	,007
	Lower-bound	1,049	1,000	1,049	,279	,600	,007
Error(stimulus)	Sphericity Assumed	150,447	40	3,761			
	Greenhouse-Geisser	150,447	40,000	3,761			
	Huynh-Feldt	150,447	40,000	3,761			
	Lower-bound	150,447	40,000	3,761			

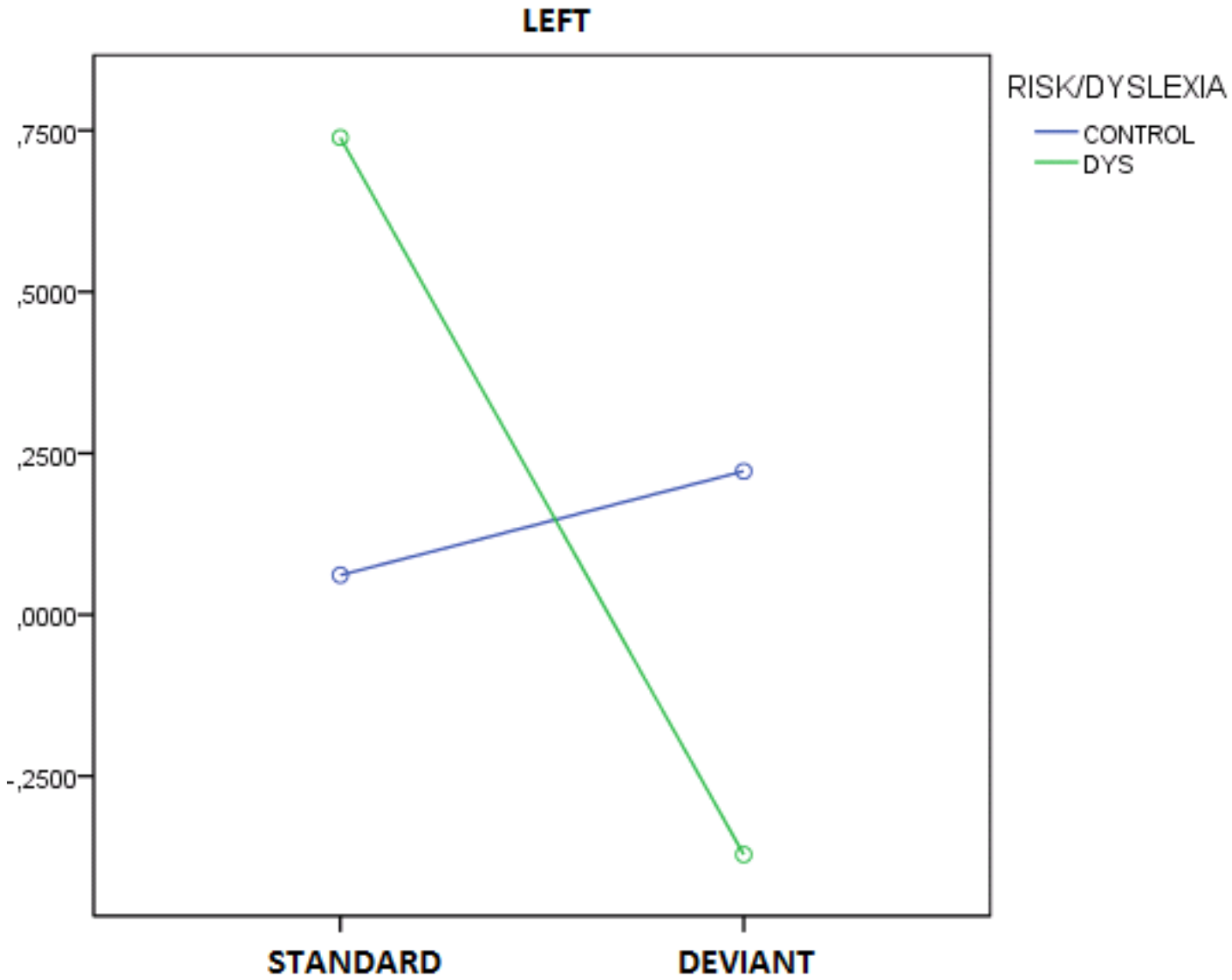
RESULTS

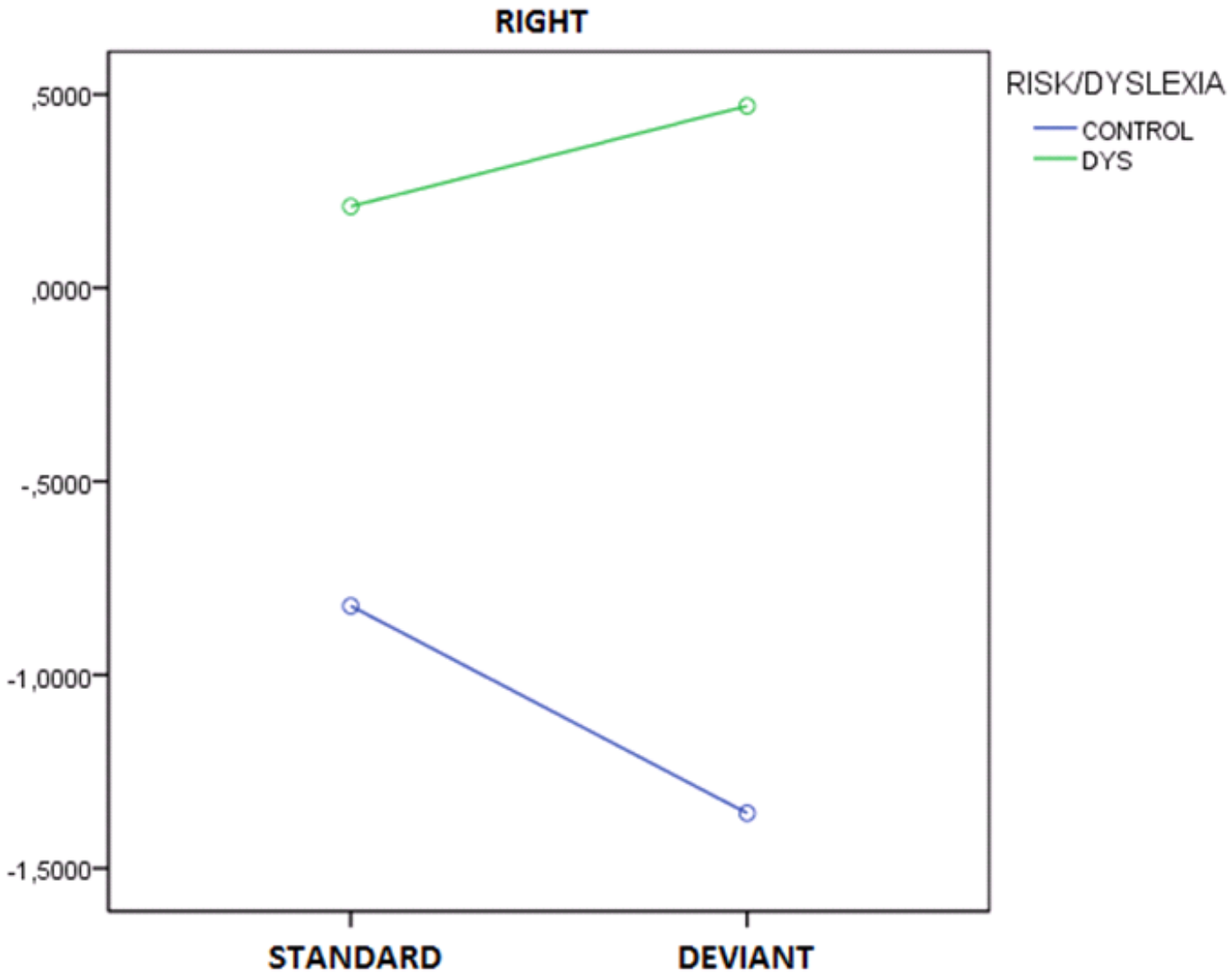
		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
location	Sphericity Assumed	11,527	2	5,763	1,508	,228	,036
	Greenhouse-Geisser	11,527	1,929	5,976	1,508	,228	,036
	Huynh-Feldt	11,527	2,000	5,763	1,508	,228	,036
	Lower-bound	11,527	1,000	11,527	1,508	,227	,036
Location * Diagnosis	Sphericity Assumed	19,217	2	9,609	2,514	,087	,059
	Greenhouse-Geisser	19,217	1,929	9,964	2,514	,089	,059
	Huynh-Feldt	19,217	2,000	9,609	2,514	,087	,059
	Lower-bound	19,217	1,000	19,217	2,514	,121	,059
Error(Location)	Sphericity Assumed	305,761	80	3,822			
	Greenhouse-Geisser	305,761	77,148	3,963			
	Huynh-Feldt	305,761	80,000	3,822			
	Lower-bound	305,761	40,000	7,644			

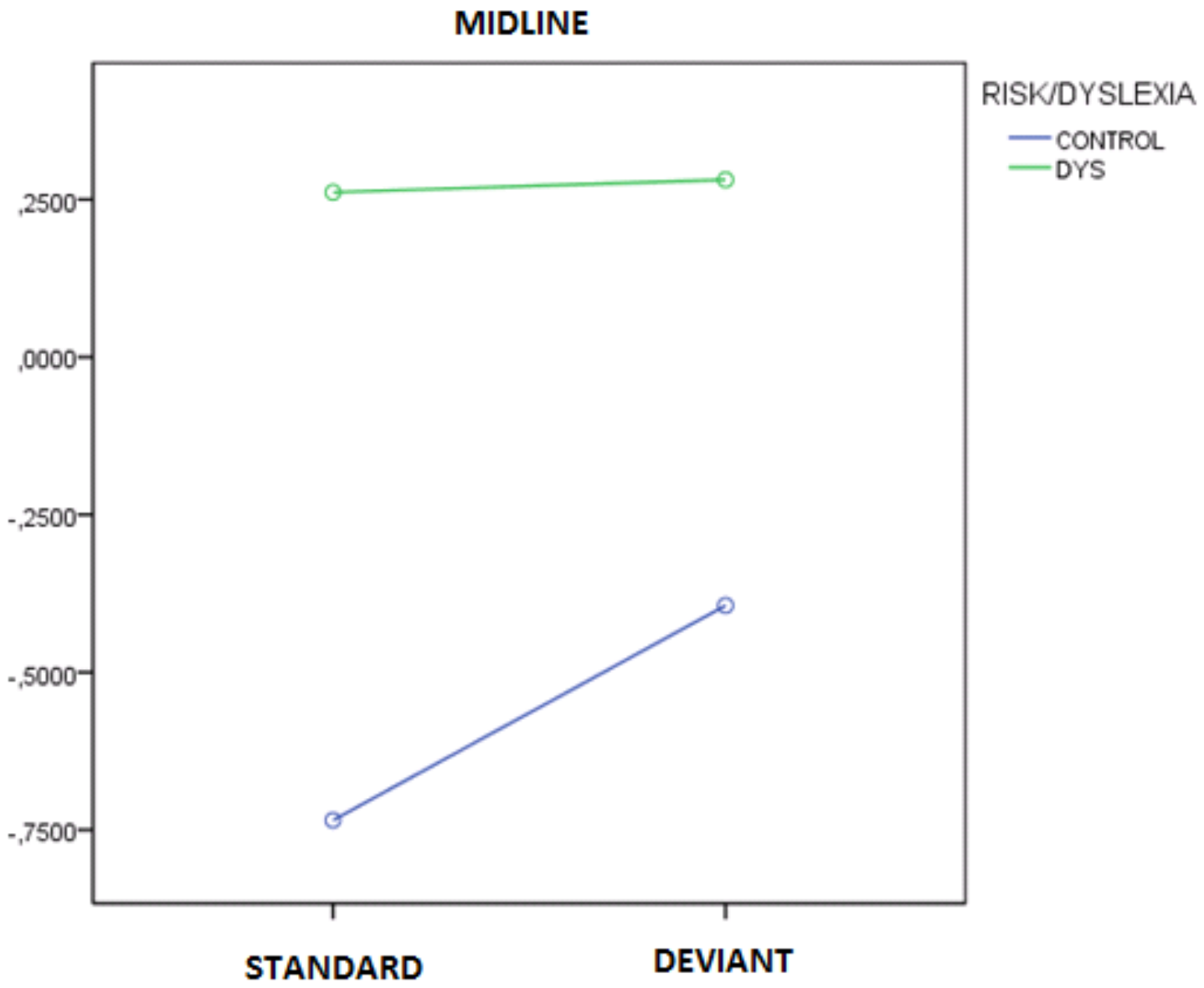
RESULTS

Source		Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
stimulus * location	Sphericity Assumed	4,250	2	2,125	,989	,377	,024
	Greenhouse-Geisser	4,250	1,847	2,301	,989	,371	,024
	Huynh-Feldt	4,250	1,981	2,145	,989	,376	,024
	Lower-bound	4,250	1,000	4,250	,989	,326	,024
stimulus * location * Diagnosis	Sphericity Assumed	10,595	2	5,297	2,465	,091	,058
	Greenhouse-Geisser	10,595	1,847	5,736	2,465	,096	,058
	Huynh-Feldt	10,595	1,981	5,348	2,465	,092	,058
	Lower-bound	10,595	1,000	10,595	2,465	,124	,058
Error(stimulus* location)	Sphericity Assumed	171,914	80	2,149			
	Greenhouse-Geisser	171,914	73,887	2,327			
	Huynh-Feldt	171,914	79,240	2,170			
	Lower-bound	171,914	40,000	4,298			

RESULTS
VISUALISING INTERACTIONS




RIGHT
,5000
,0000
-,5000
-1,0000
-1,5000
STANDARD
DEVIANT
RISK/DYSLEXIA
CONTROL
DYS


MIDLINE
RISK/DYSLEXIA
CONTROL
DYS
,2500
,0000
-,2500
-,5000
-,7500
STANDARD
DEVIANT

DISCUSSION

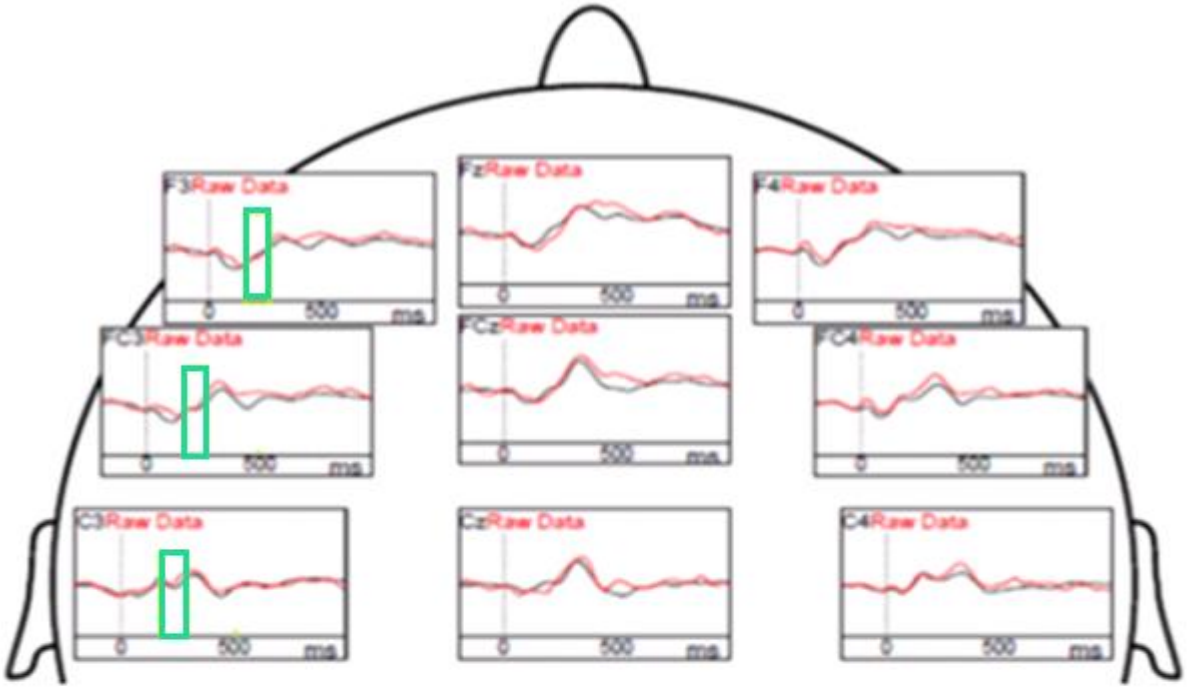
- No significant effects
- Looking at the interactions:
  - If there would be a significant effect, this would be opposite of what is expected

    → it seems like the dyslectic children show a much larger difference between standard & deviant in the left hemisphere than the control group.

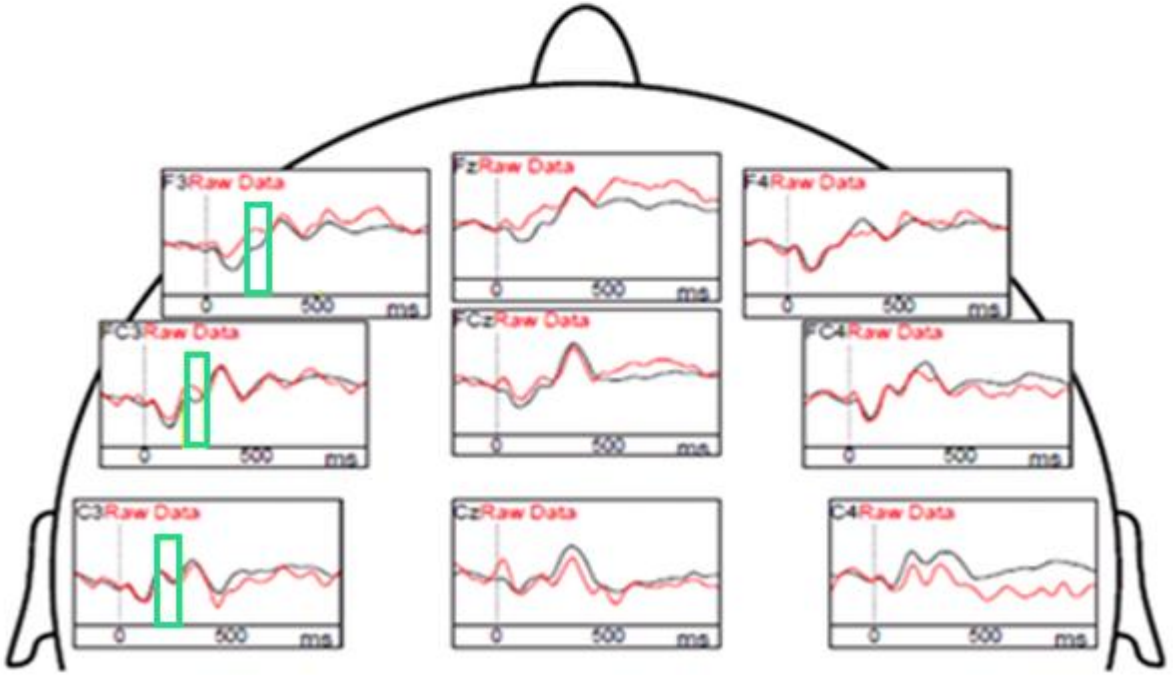
DISCUSSION

- Explanation for results:
  - Perhaps the dyslectic children do notice subtle differences between phonemes, but processing might be slower
    - Test latency instead of amplitude

- No dyslexia



- Dyslexia



QUESTIONS?