

Overnight dynamics in scale-free and oscillatory spectral parameters of NREM sleep EEG: can polysomnography provide an insight into sleep regulation?

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Dynamics of slope and SWA throughout the night

Effect	Repeated Measures Analysis of Variance Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 1,0384				
	SS	Degr. of	MS	F	p
<i>Intercept</i>	42215.40	1	42215.40	39150.55	0.000000
<i>{1}agegroups</i>	55.16	3	18.39	17.05	0.000000
<i>{2}sex</i>	0.00	1	0.00	0.00	0.973866
<i>agegroups*sex</i>	3.10	3	1.03	0.96	0.412888
<i>Error</i>	250.16	232	1.08		
<i>{3}CYCLE</i>	111.95	3	37.32	210.78	0.000000
<i>CYCLE*agegroups</i>	23.90	9	2.66	15.00	0.000000
<i>CYCLE*sex</i>	0.55	3	0.18	1.04	0.376093
<i>CYCLE*agegroups*sex</i>	1.42	9	0.16	0.89	0.534983
<i>Error</i>	123.22	696	0.18		
<i>{4}REGION</i>	37.72	4	9.43	211.14	0.000000
<i>REGION*agegroups</i>	1.96	12	0.16	3.66	0.000021
<i>REGION*sex</i>	0.03	4	0.01	0.17	0.954290
<i>REGION*agegroups*sex</i>	0.31	12	0.03	0.57	0.864328
<i>Error</i>	41.45	928	0.04		
<i>{5}LEFTRIGH</i>	0.05	1	0.05	1.14	0.286561

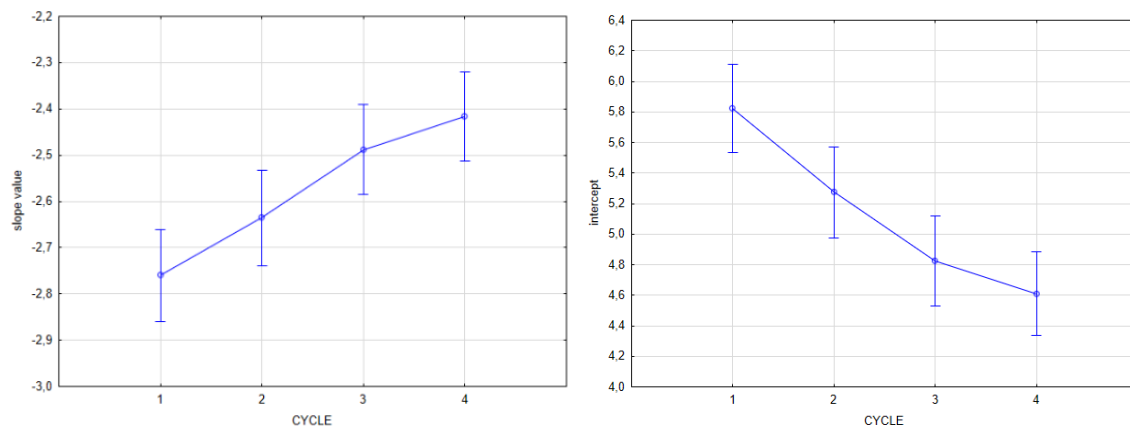
LEFTRIGH*agegroups	0.16	3	0.05	1.17	0.322241
LEFTRIGH*sex	0.03	1	0.03	0.72	0.396967
LEFTRIGH*agegroups*sex	0.06	3	0.02	0.41	0.742940
Error	10.35	232	0.04		
CYCLE*REGION	1.71	12	0.14	51.92	0.000000
CYCLE*REGION*agegroups	0.22	36	0.01	2.26	0.000030
CYCLE*REGION*sex	0.02	12	0.00	0.51	0.906762
CYCLE*REGION*agegroups*sex	0.07	36	0.00	0.70	0.905938
Error	7.62	2784	0.00		
CYCLE*LEFTRIGH	0.03	3	0.01	0.78	0.503127
CYCLE*LEFTRIGH*agegroups	0.16	9	0.02	1.50	0.144534
CYCLE*LEFTRIGH*sex	0.07	3	0.02	2.14	0.094022
3*5*1*2	0.14	9	0.02	1.31	0.226210
Error	8.02	696	0.01		
REGION*LEFTRIGH	0.48	4	0.12	9.97	0.000000
REGION*LEFTRIGH*agegroups	0.18	12	0.02	1.28	0.225233
REGION*LEFTRIGH*sex	0.06	4	0.01	1.17	0.324167
4*5*1*2	0.26	12	0.02	1.80	0.044568
Error	11.11	928	0.01		
CYCLE*REGION*LEFTRIGH	0.02	12	0.00	1.93	0.026539
3*4*5*1	0.04	36	0.00	1.06	0.369057
CYCLE*REGION*LEFTRIGH*sex	0.01	12	0.00	0.61	0.834775
CYCLE*REGION*LEFTRIGH**sex	0.05	36	0.00	1.29	0.113370
Error	2.93	2784	0.00		

Suppl. Table 1. General linear model about the spectral slopes with between subject factors age and sex, within subject factors cycle, region and left/right positions of the electrodes.

age group	C1 vs. C2 p-value	C2 vs. C3 p-value	C3 vs. C4 p-value	M _{C1} SD	M _{C2} SD	M _{C3} SD	M _{C4} SD
y. adult	0.000	0.000	0.048	-2.68 0.017	-2.59 0.018	-2.50 0.017	-2.44 0.016
child	0.000	0.000	0.644	-3.10 0.037	-2.83 0.038	-2.57 0.036	-2.50 0.036
m. adult	1.000	0.052	0.591	-2.57 0.036	-2.54 0.038	-2.43 0.035	-2.35 0.035
teenager	0.034	0.012	0.452	-2.69 0.034	-2.58 0.035	-2.46 0.033	-2.38 0.032

Suppl. Table 2. Results of post hoc test about the cycle x age group interaction with respect to spectral slope. The table displays the difference between cycles in particular age groups. Abbreviations: y. adult -young adult, m. adult- middle-aged adult, C1- 1st sleep cycle, C2- 2nd sleep cycle, C3- 3rd sleep cycle, C4- 4th sleep cycle, M- mean, SD- standard deviation

Is there a cycle dynamic of the alternative intercepts?



Suppl. Fig.1. Dynamics of slope and intercept values in the course of sleep for the first 4 consecutive sleep cycles. On the left side: slope by cycle, on the right: intercepts by cycle effects can be seen.

Effect	Repeated Measures Analysis of Variance Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 2,1572				
	SS	Degr. of Freedom	MS	F	p
Intercept	10848,54	1	10848,54	2331,166	0,000000
{1}agegroups	1408,89	3	469,63	100,916	0,000000
{2}sex	44,80	1	44,80	9,627	0,002155
agegroups*sex	49,25	3	16,42	3,527	0,015669
Error	1079,66	232	4,65		
{3}CYCLE	122,38	3	40,79	339,928	0,000000
CYCLE*agegroups	3,22	9	0,36	2,983	0,001707
CYCLE*sex	0,76	3	0,25	2,123	0,095945
CYCLE*agegroups*sex	0,68	9	0,08	0,631	0,770865
Error	83,53	696	0,12		
{4}REGION	138,21	4	34,55	110,711	0,000000
REGION*agegroups	18,56	12	1,55	4,957	0,000000
REGION*sex	6,88	4	1,72	5,510	0,000219
REGION*agegroups*sex	2,57	12	0,21	0,688	0,764650
Error	289,62	928	0,31		
{5}LEFTRIGH	0,12	1	0,12	0,617	0,433062
LEFTRIGH*agegroups	1,20	3	0,40	2,136	0,096398
LEFTRIGH*sex	0,04	1	0,04	0,210	0,647546
LEFTRIGH*agegroups*sex	0,02	3	0,01	0,042	0,988472
Error	43,54	232	0,19		
CYCLE*REGION	0,80	12	0,07	6,973	0,000000
CYCLE*REGION*agegroups	0,42	36	0,01	1,229	0,164623
CYCLE*REGION*sex	0,15	12	0,01	1,282	0,222071
CYCLE*REGION*agegroups*sex	0,35	36	0,01	1,003	0,463680
Error	26,72	2784	0,01		
CYCLE*LEFTRIGH	0,02	3	0,01	0,298	0,826796
CYCLE*LEFTRIGH*agegroups	0,33	9	0,04	1,507	0,141319
CYCLE*LEFTRIGH*sex	0,21	3	0,07	2,850	0,036667
3*5*1*2	0,20	9	0,02	0,897	0,527368
Error	16,91	696	0,02		
REGION*LEFTRIGH	0,15	4	0,04	0,440	0,779783
REGION*LEFTRIGH*agegroups	2,20	12	0,18	2,121	0,013724

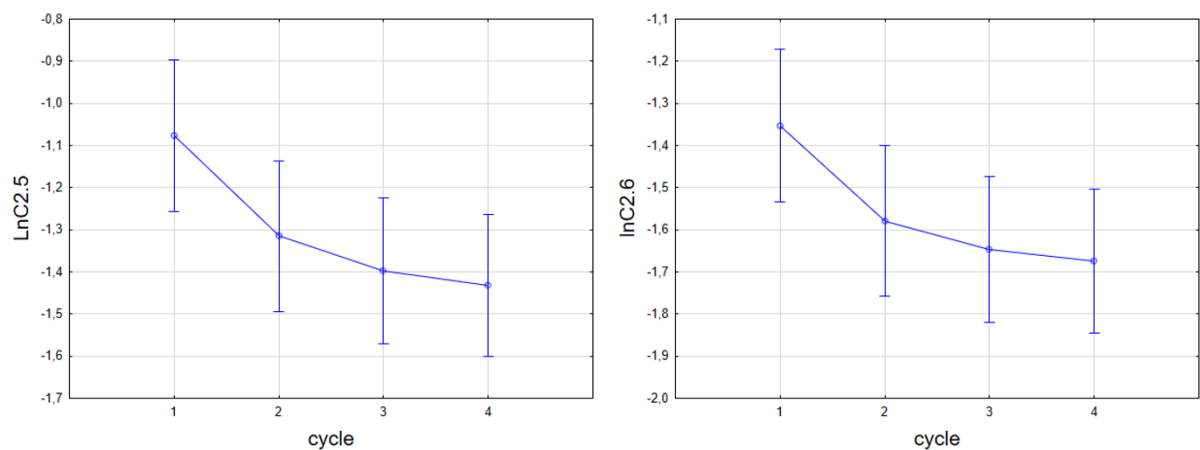
REGION*LEFTRIGH*sex	0,63	4	0,16	1,812	0,124323
4*5*1*2	1,62	12	0,13	1,559	0,098071
Error	80,27	928	0,09		
CYCLE*REGION*LEFTRIGH	0,18	12	0,02	3,018	0,000318
3*4*5*1	0,30	36	0,01	1,651	0,008792
CYCLE*REGION*LEFTRIGH*sex	0,09	12	0,01	1,493	0,119128
CYCLE*REGION*LEFTRIGH**sex	0,24	36	0,01	1,319	0,097453
Error	14,04	2784	0,01		

Suppl. Table 3. General linear model of alternative intercept lnC2.5

Effect	Repeated Measures Analysis of Variance Sigma-restricted parameterization Effective hypothesis decomposition; Std. Error of Estimate: 2,1718				
	SS	Degr. of Freedom	MS	F	p
Intercept	15550,77	1	15550,77	3296,844	0,000000
{1}agegroups	1359,26	3	453,09	96,057	0,000000
{2}sex	44,85	1	44,85	9,508	0,002294
agegroups*sex	47,74	3	15,91	3,374	0,019188
Error	1094,31	232	4,72		
{3}CYCLE	101,33	3	33,78	274,841	0,000000
CYCLE*agegroups	2,00	9	0,22	1,805	0,063971
CYCLE*sex	0,88	3	0,29	2,390	0,067594
CYCLE*agegroups*sex	0,70	9	0,08	0,634	0,768312
Error	85,54	696	0,12		
{4}REGION	124,40	4	31,10	101,964	0,000000
REGION*agegroups	18,67	12	1,56	5,100	0,000000
REGION*sex	6,84	4	1,71	5,607	0,000184
REGION*agegroups*sex	2,52	12	0,21	0,689	0,763620
Error	283,04	928	0,31		
{5}LEFTRIGH	0,13	1	0,13	0,663	0,416267
LEFTRIGH*agegroups	1,26	3	0,42	2,112	0,099426
LEFTRIGH*sex	0,05	1	0,05	0,236	0,627857
LEFTRIGH*agegroups*sex	0,03	3	0,01	0,043	0,988247
Error	46,03	232	0,20		
CYCLE*REGION	0,67	12	0,06	5,796	0,000000
CYCLE*REGION*agegroups	0,41	36	0,01	1,174	0,220499

CYCLE*REGION*sex	0,15	12	0,01	1,326	0,196324
CYCLE*REGION*agegroups*sex	0,35	36	0,01	1,004	0,462236
Error	26,80	2784	0,01		
CYCLE*LEFTRIGH	0,03	3	0,01	0,318	0,812316
CYCLE*LEFTRIGH*agegroups	0,36	9	0,04	1,469	0,155448
CYCLE*LEFTRIGH*sex	0,22	3	0,07	2,724	0,043419
3*5*1*2	0,22	9	0,02	0,919	0,507941
Error	18,78	696	0,03		
REGION*LEFTRIGH	0,14	4	0,04	0,401	0,807816
REGION*LEFTRIGH*agegroups	2,27	12	0,19	2,113	0,014134
REGION*LEFTRIGH*sex	0,66	4	0,17	1,847	0,117810
4*5*1*2	1,73	12	0,14	1,612	0,082725
Error	83,00	928	0,09		
CYCLE*REGION*LEFTRIGH	0,17	12	0,01	2,855	0,000647
3*4*5*1	0,31	36	0,01	1,699	0,005908
CYCLE*REGION*LEFTRIGH*sex	0,09	12	0,01	1,512	0,111992
CYCLE*REGION*LEFTRIGH**sex	0,25	36	0,01	1,357	0,076776
Error	14,14	2784	0,01		

Suppl. Table 4. General linear model of alternative intercept lnC2.6



Suppl. Fig. 2. Cycle dynamics of the alternative intercepts.

Can the classical measure of sleep homeostasis (lnSWA) be predicted by the spectral slope and alternative intercepts?

cycle	F	df	p	R ²	Adjusted R ²	predictor s	b*	b	t	p
1	334. 8	2,248	0.000	0.73	0.73	slope	-0.44	-	-12.44	0.000
						lnC2.5	0.59	2503.06 1491.05	16.77	0.000
2	187. 8	2,248	0.000	0.6	0.599	slope	-0.39	-823.1	-9.61	0.000
						lnC2.5	0.59	507.23	14.47	0.000
3	172. 9	2,246	0.000	0.58 4	0.581	slope	-0.36	-337.53	-8.62	0.000
						lnC2.5	0.63	226.94	15.32	0.000
4	123. 3	2,237	0.000	0.51	0.51	slope	-0.45	-178.57	-9.92	0.000
						lnC2.5	0.56	87.669	12.41	0.000
5	41.2 8	2,72	0.000	0.53	0.52	slope	-0.35	-138.34	-4.33	0.000
						lnC2.5	0.599	75.91	7.4	0.000
1	334. 8	2,248	0.000	0.73	0.73	slope	-0.47	-	-13.38	0.000
						lnC2.6	0.58	2652.17 1491.04	16.78	0.000
2	187. 8	2,248	0.000	0.6	0.6	slope	-0.42	-873.82	-10.28	0.000
						lnC2.6	0.59	507.24	14.47	0.000
3	172. 9	2,246	0.000	0.58	0.58	slope	-0.38	-360.22	-9.24	0.000
						lnC2.6	0.63	226.94	15.32	0.000
4	123. 3	2,237	0.000	0.51	0.51	slope	-0.47	-187.33	-10.39	0.000
						lnC2.6	0.57	87.669	12.41	0.000
5	41.2 8	2,72	0.000	0.53	0.52	slope	-0.37	-145.93	-4.58	0.000
						lnC2.6	0.6	75.913	7.4	0.000

Suppl. Table 5. Predictability of NREM sleep EEG SWA by using regression models with spectral slopes and alternative intercepts as predictors.

Overnight change in the frequencies of the maximal peaks in the spindle frequency range (9-18 Hz)

agegroups	Ch	T	Y	M	Mean	S.E.	-95%	95%	N
Children		0.000	0.000	0.000	11.92	0.18	11.57	12.27	9
Teenagers	0.000		0.984	0.947	12.95	0.09	12.78	13.12	33
Young adults	0.000	0.984		0.994	12.91	0.04	12.82	13.00	125
Middle-aged adults	0.000	0.947	0.994		12.89	0.11	12.68	13.11	22

Suppl. Table 6. P-values and descriptives of post hoc test on age effect. Ch-children, T-teenagers, Y-young adults, M-middle aged adults.

REGION	Fp	F	C	P	O	Mean	S.E.	-95%	95%	N
Fp		0.000	0.000	0.000	0.000	11.81	0.08	11.65	11.97	189
F	0.000		0.000	0.000	0.000	12.18	0.09	12.01	12.35	189
C	0.000	0.000		0.001	0.010	12.96	0.07	12.82	13.10	189
P	0.000	0.000	0.001		0.978	13.18	0.06	13.05	13.30	189
O	0.000	0.000	0.010	0.978		13.22	0.06	13.10	13.34	189

Suppl. Table 7. P-values and descriptives of post hoc test on region effect. Fp-frontopolar, F-frontal, C-central, P-parietal, O-occipital.

Region	C1 vs. C2	C2 vs. C3	C3 vs. C4	MC1	SD	MC2	SD	MC3	SD	MC4	SD
Frontopolar	0.000	0.980	0.000	11.85	0.10	11.67	0.11	11.66	0.09	12.04	0.09
Frontal	0.167	0.001	0.000	11.95	0.11	12.06	0.10	12.23	0.10	12.48	0.09
Central	1.000	0.940	1.000	12.85	0.11	12.93	0.09	12.99	0.08	13.06	0.08
Parietal	0.043	1.000	0.930	13.23	0.08	13.11	0.08	13.12	0.07	13.24	0.07
Occipital	0.109	0.999	0.507	13.30	0.08	13.11	0.07	13.12	0.06	13.36	0.07

Suppl. Table 8. Post hoc test of region x cycle interaction. MC = Mean value of the sleep cycle; SD = standard deviation

Region	M _{ch} (N=9)	SD	M _t (N=33)	SD	M _y (N=125)	SD	M _m (N=22)	SD
Fp	11.44	0.25	12.25	0.12	11.98	0.06	11.56	0.15
F	11.63	0.27	12.72	0.13	12.39	0.07	11.98	0.17
C	11.99	0.22	13.16	0.11	13.32	0.06	13.36	0.14
P	12.20	0.20	13.28	0.10	13.47	0.05	13.76	0.12
O	12.34	0.18	13.34	0.09	13.40	0.05	13.82	0.11

Suppl. Table 9. Means and standard deviations of $F_{maxPeak}$ values in different age groups on different regions. Markings are the following: M-mean, SD-standard deviation, ch=children, t=teenager, y=young adult, m=middle-aged adult, Fp-Frontopolar region, F-Frontal region, C-central region, P-parietal region, O-Occipital region

Region	y vs. ch	y vs. m	y vs. t	ch vs. m	ch vs. t	m vs. t
Fp	0.995	0.809	0.978	1.000	0.672	0.044
F	0.796	0.769	0.805	1.000	0.090	0.008
C	0.002	1.000	1.000	0.002	0.016	1.000
P	0.003	0.999	1.000	0.000	0.029	0.719
O	0.021	0.879	1.000	0.000	0.046	0.658

Suppl. Table 10. *P* values of post hoc test about the region x age group interactions. Markings: ch=children, t=teenagers, y=young adults, m=middle-aged adults, Fp-frontopolar region, F-frontal region, C-central region, P-parietal region, O-occipital region

	1. cycle (%)	2. cycle (%)	3. cycle (%)	4. cycle (%)
F-Fp	17.53	31.47	45.02	38.25
C-F	54.18	50.60	41.83	40.64
P-C	15.54	5.98	4.78	8.76
O-P	3.98	4.38	2.79	4.78

Suppl. Table 11. Percentage distribution of the location of maximal frequency shifts in the sample. Meaning of markings are the following: F-Fp: frontal-to-frontopolar, C-F: central-to-frontal, P-C: parietal-to-central, O-P: occipital-parietal. Numbers mean the percent of the occurrence of the maximum frequency shift in a given area.

Cycle effects on spectral peak amplitudes

age group	C1 vs. C2	C2 vs. C3	C3 vs. C4
child	0.031	0.137	1.000
teenager	0.000	0.073	0.999
y.adult	0.000	0.000	0.001
m.adult	1.000	0.973	1.000

Suppl. Table 12. *p* values of the post hoc test for the cycle effect on peak amplitudes in the different age groups. C1 vs. C2 – difference between cycle 1 and cycle 2, C2 vs. C3- difference between cycle 2 and cycle 3, C3 vs. C4- difference between cycle 3 and cycle 4

	child	SD	teenager	SD	y. adult	SD	m. adult	SD
cycle 1	0.94	0.15	1.67	0.07	1.85	0.04	1.60	0.09
cycle 2	1.28	0.16	1.92	0.08	2.04	0.04	1.67	0.10
cycle 3	1.49	0.16	2.07	0.08	2.15	0.04	1.76	0.10
cycle 4	1.63	0.16	2.13	0.08	2.26	0.04	1.77	0.10

Suppl. Table 13. Mean values and standard dev.s(SD) of cycle x age group interaction