Prefrontal Neurofeedback Training Approaches in Autism

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Introduction & Background

➤ Electroencephalographic (EEG) biofeedback training (so called brainwave neurofeedback) is a treatment potentially useful for improvement of self-regulation skills in autism spectrum disorder (ASD).

➤We proposed that prefrontal neurofeedback training will be accompanied by changes in relative power of EEG bands and ratios of individuals bands (e.g., theta/beta ratio).

➤In the first pilot study on 8 children and adolescents with ASD (~17.4 yrs) we used 12 session long course of prefrontal neurofeedback from AFz site, while in the second study on 18 children (~13.2 yrs) we administered 18 sessions of 25 min long prefrontal neurofeedback training.

➤The protocol used a training procedure, which according to specifications, represents wide band EEG amplitude suppression with simultaneous upregulation of 40 Hz centered gamma activity.

➤ Quantitative EEG analysis (qEEG) at the training site was completed for each session of neurofeedback using a custom-made MATLAB application to determine the relative power of the individual bands (delta, theta, alpha, low beta, high beta, and gamma) and their ratios (theta/low beta, theta/high beta, etc.) within and between sessions.

➤The measures that showed significant changes in the pilot were selected as dependent variables for qEEG in the second study. In particular, we performed analysis of relative power of gamma and theta/beta ratios.

➤Using our custom-made MATLAB application based on wavelet transformation, we were able to detect changes in the relative power and band ratios during the neurofeedback course, specifically linear decrease of theta/beta ratio and increase of 40 Hz centered gamma over 18 sessions of neurofeedback in 18 children with ASD.

➤The pilot study that used only 12 sessions showed significant qEEG changes sessions but did show only trend of progress across the 12 sessions even though changes of individual EEG bands and their ratios were significant.
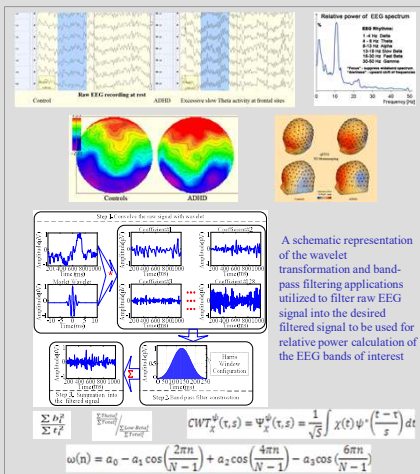
➤Our experiments showed advantages of 18 session long weekly prefrontal neurofeedback course in children with autism.

➤ More future research is needed to assess qEEG changes at other topographies using brain mapping and using other outcome measures including behavioral evaluations to judge about clinical utility of prefrontal neurofeedback in children with ASD.

➤Current study was focused mostly on technical aspects of recorded EEG pre-processing and quantitative analysis.

EEG analysis method

A schematic representation of the wavelet transformation and band-pass filtering applications utilized to filter raw EEG signal into the desired filtered signal to be used for relative power calculation of the EEG bands of interest

$$\frac{\sum b_i^2}{\sum t_i^2}$$

$$CWT_x^\psi(\tau,s) = \Psi_x^\psi(\tau,s) = \frac{1}{\sqrt{s}} \int \chi(t)\psi^*\left(\frac{t-\tau}{s}\right) dt$$

$$\omega(n) = a_0 - a_1 \cos\left(\frac{2\pi n}{N-1}\right) + a_2 \cos\left(\frac{4\pi n}{N-1}\right) - a_3 \cos\left(\frac{6\pi n}{N-1}\right)$$
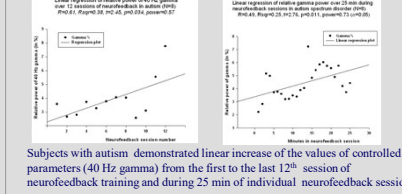
Method: Equipment

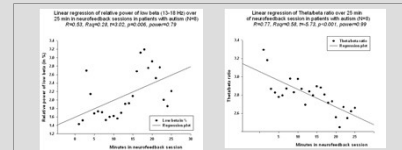**PAT neurofeedback: feedback screen and prefrontal sensor position**

Subjects in 2 studies

➤ Eight children were enrolled in the first pilot study (mean 14.2 years, SD= 4.7, 27 boys, 12 sessions of neurofeedback)

➤ Eighteen children and adolescents with ASD (mean 13.2 years, SD=4.3, 14 boys) were enrolled in the second study (18 sessions of neurofeedback).

➤Participants were recruited through the Weisskopf Child Evaluation Center .

➤ Diagnosis was made according to DSM-IV-TR and further ascertained with the Autism Diagnostic Interview – Revised (ADI-R).

➤14 participants were high-functioning persons with autism diagnosis and 4 had Asperger Syndrome. All had full-scale IQ > 80 assessed using WISC-IV.

➤ All IRB-approved consent/assent forms were signed by participants and their parents/guardians.

Study 1: Changes across 12 sessions (N=8)

Subjects with autism demonstrated linear increase of the values of controlled parameters (40 Hz gamma) from the first to the last 12th session of neurofeedback training and during 25 min of individual neurofeedback session.

Low beta and Theta/beta ratio during 25 min long session (N=8)

Linear regression analysis in Study 2

Autism group (N=18, 18 sessions of neurofeedback)
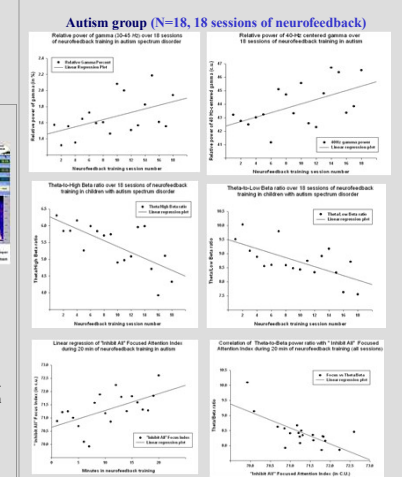
Behavioral Clinical Evaluation Measures Post-Neurofeedback (Study 2)

Behavioral evaluations

There was found a significant reduction in **Lethargy** subscale of the ABC. The rating scores showed reduction (from 10.18 ± 6.07 to 7.53± 5.82, change was -2.644 ± 3.13, t(17)=3.29, p=0.005), while **Hyperactivity** scores also showed decrease (from 16.65 ±13.78 to 13.29 ± 11.97, -3.35 ± 5.39, t(17)=2.56, p=0.021).

Statistical outcomes of Study 2: Linear regression and pre-post changes

Measures	Units	t	P-value	Regression Equation	Power
Gamma	%	2.25	.039	.491	y=.022x+1.45	.548
Theta/Low Beta	N/A	-3.57	.003	.666	y=-.079x+9.49	.876
Theta/High Beta	N/A	-4.01	.001	.708	y=-.088x+6.26	.928
"Focus Attention" Index	C.E.	1.84	.084	.418	.175	y=.056x+73.93	.408
"40Hz Gamma" Index	C.E.	2.61	.019	.547	.299	y=.165x+42.37	.662

| EEG Measures Last-minus-first | Units | Paired Differences | | 95% CI | | | | |
		Mean	Std. Dev.	Lower	Upper	t	df	P-value
Gamma	%	.22	1.24	-.84	.39	.76	17	.456
Theta/Low Beta	N/A	-1.72	3.40	-.032	3.42	-2.15	17	.046
Theta/High Beta	N/A	-1.48	2.83	.081	2.89	-2.23	17	.039
Theta/Beta	N/A	-4.26	2.47	.033	2.49	-2.16	17	.045
"Focused Attention"	C.E.	2.29	2.25	-3.41	-1.17	4.32	17	.001
"40Hz-gamma"	C.E.	3.68	6.66	-7.08	-.37	2.34	17	.031

Summary: Study 2

➤ Neurofeedback training aimed at enhancement of the "Focused Attention" index and "40 Hz-centered gamma" index measures in autism group was accompanied by improved in Lethargy and Hyperactivity by the Aberrant Behavior Checklist (ABC) inventory.

➤ Self-regulation of prefrontal EEG measures of "Focused Attention" and "40 Hz-centered Gamma" indices using protocol with DVD-control as a visual feedback along with auditory feedback was effective in maintaining interest and motivational engagement of children with autism.

➤ Twelve 25 min long sessions of neurofeedback (Study 1) were sufficient to achieve ability to control EEG parameters of interest during session but was less efficient in transfering effects across the neurofeedback course. Eighteen session long course resulted in statistically significant regression of dependent variables across the course of training in Study 2.

➤ Neurofeedback effects in the autism group were expressed in increased relative power of gamma band, decreased Theta/beta and Theta/low beta ratios.

➤ Custom-made Matlab program developed for the analysis of EEG data using wavelet analysis was useful to detect changes in EEG profiles during neurofeedback sessions.

References

1. Aman, M.G., & Singh, N.N. (1994). *Aberrant Behavior Checklist - Community. Supplementary Manual.* East Aurora, NY: Slosson Ed. Publications.
2. Wang, Y., Li, X., Sears, L., Casanova, M., Tasman, A., & Sokhadze, E. (2014) A study of relative power of specific EEG bands and their ratios during neurofeedback training in children with autism spectrum disorder. *Novel Computational Tools in Biosignal Processing (submitted)*