

Prefrontal neurofeedback training outcomes in children with autism spectrum disorder (ASD) with comorbid attention deficit/hyperactivity disorder (ADHD)

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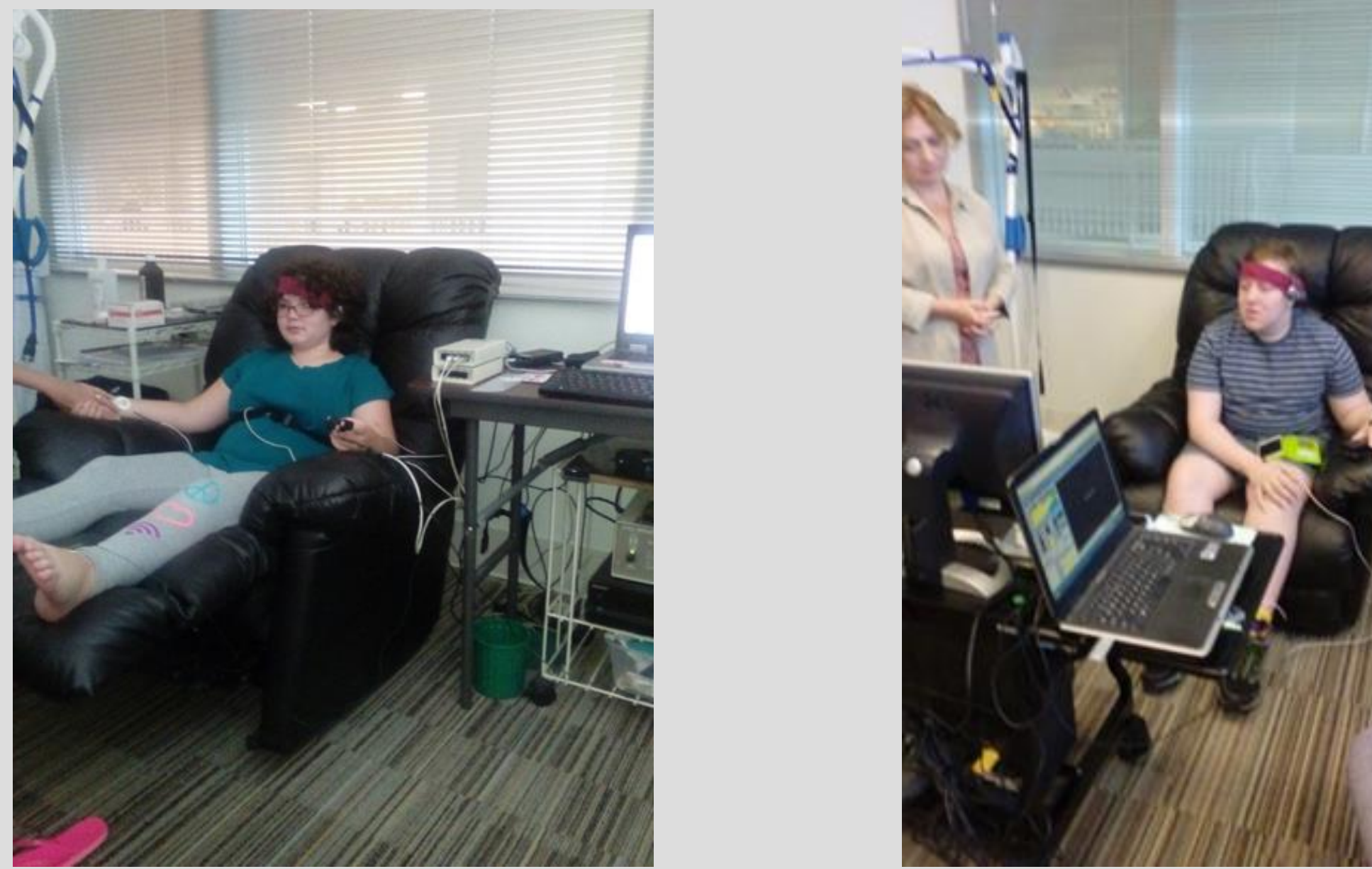
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Abstract

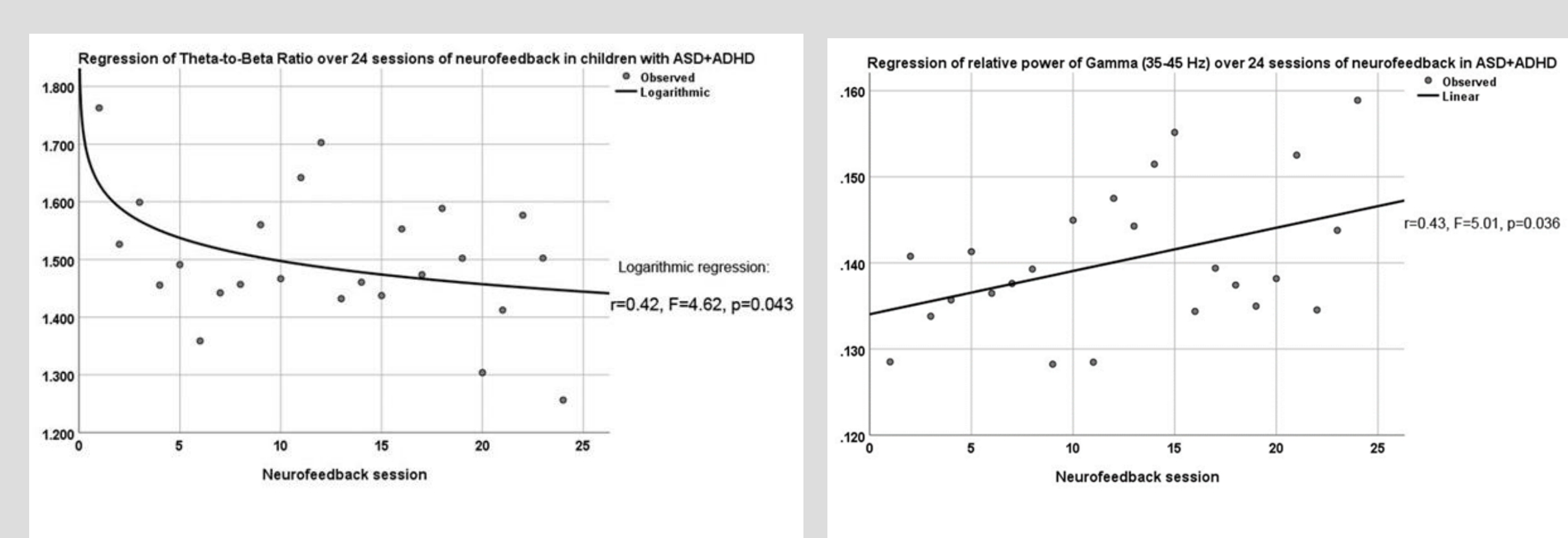
- Neurofeedback (electroencephalographic [EEG] biofeedback [NFB]) is one of the promising methods for training brainwave activity in children with autism spectrum disorder (ASD) and children with ADHD. There are several neurofeedback protocols proposed for ASD with most differences being in the type of training (e.g., theta/beta ratio, coherence), topography (Cz or Pz), guidance by quantitative EEG (qEEG) and number of sessions (e.g., 20 vs. 30, etc.). We proposed that 24 sessions of prefrontal neurofeedback training will be accompanied by changes in power of targeted EEG bands (e.g., 40 Hz centered gamma band) and ratios of individual bands (e.g., theta/beta ratio), as well as in electrodermal and cardiorespiratory indices and result in improved behavioral scores.
- Outcomes measures along with EEG, ECG, pneumogram and skin conductance measures included behavioral ratings by parents. The protocol used a training for wide band EEG amplitude suppression ("InhibitAll") with simultaneous upregulation of the relative power of 40 Hz-centered gamma subband activity.
- Most of studies of neurofeedback in ASD and ADHD focus on behavioral and EEG outcomes and do not analyze associated psychophysiological processes during successful training. In a pilot study on 10 children diagnosed with ASD and comorbid ADHD (10.3 years, SD=1.93, 3 girls) in a 24 session-long course aimed at 40 Hz gamma upregulation and theta-to-beta ratio downregulation we recorded ECG, pneumogram and electrodermal activity.
- QEEG analysis at the training site was completed for each session of neurofeedback to determine the relative power of the individual bands (theta, beta, and gamma) and their ratios (theta/beta) within and between sessions. We analyzed Aberrant Behavior Checklist (ABC), SRS-2 and ASEBA ratings by parents (pre- and post-NFB).
- Dynamics of autonomic measures were analyzed during each neurofeedback session and across the whole course. Regression analysis revealed significant linear increase of skin conductance level (SCL, $p < 0.001$) along with decrease of heart rate (HR, $p = 0.021$) across the course of training. Heart rate variability (HRV) measures (e.g., RMSSD of HR and LF/HF of HRV) showed significant increase across the course of NFB training. According to parental reports hyperactivity ($p = 0.04$) and attention-related problems ($p = 0.029$) and social responsiveness T-score (0.031) decreased by the end of 24 session-long neurofeedback course.
- Psychophysiological measures represent useful markers of attention and emotional engagement of children with ASD and ADHD during neurofeedback and can be used as predictors of successful performance during training sessions and general behavioral outcome of the intervention.
- In particular, trend towards increase of electrodermal activity along with HR deceleration and increased indices of respiratory sinus arrhythmia in HRV may reflect more active attention to training targets and/or experience of emotion states reflected in observed pattern of psychophysiological indices.

Neurofeedback setting

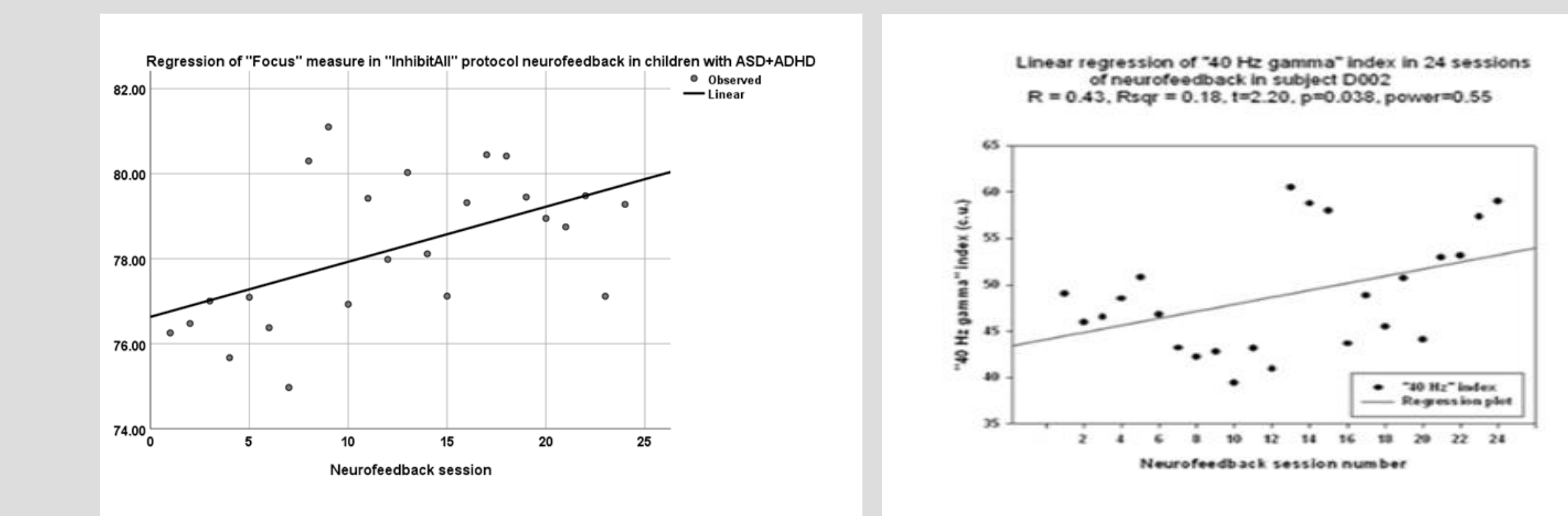
Neurofeedback setting in the Center of Childhood Neurotherapeutics of USC-School of Medicine-Greenville and GHS/Prisma Health at Developmental-Behavioral division of Children's Hospital at Patewood Memorial Campus in Greenville, SC.



Changes of EEG (theta/beta and gamma) during NF course



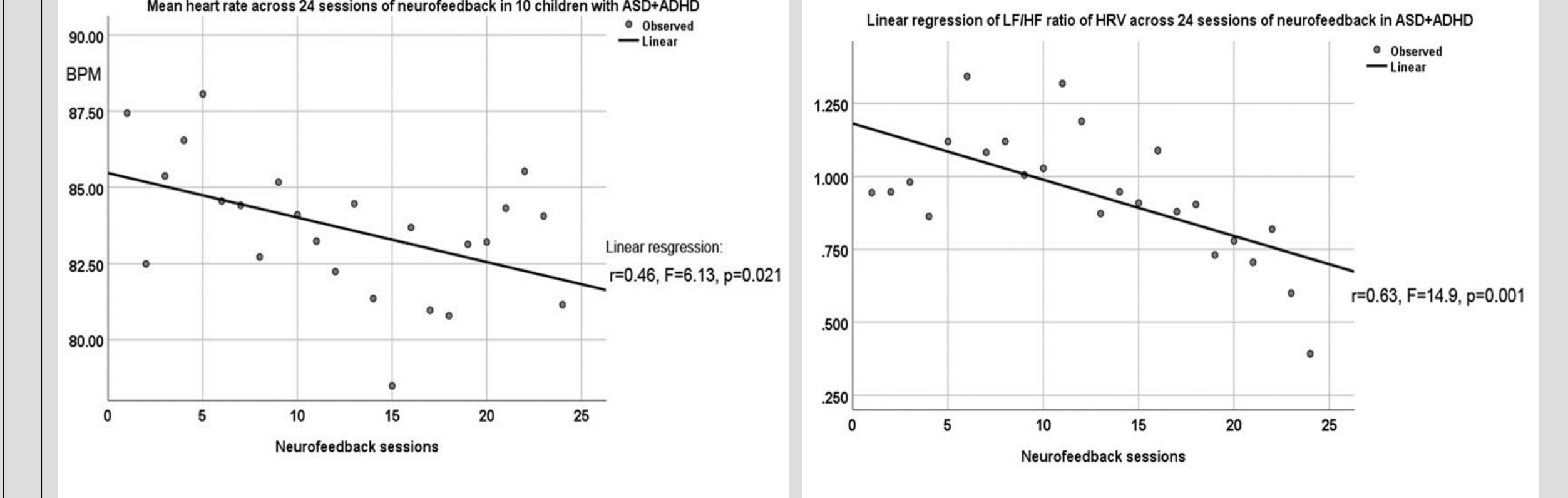
Linear regression of neurofeedback training target indices ("Focus" and "Neureka!") during 24 neurofeedback session



ABC and ASEBA behavioral evaluation measures post-neurofeedback

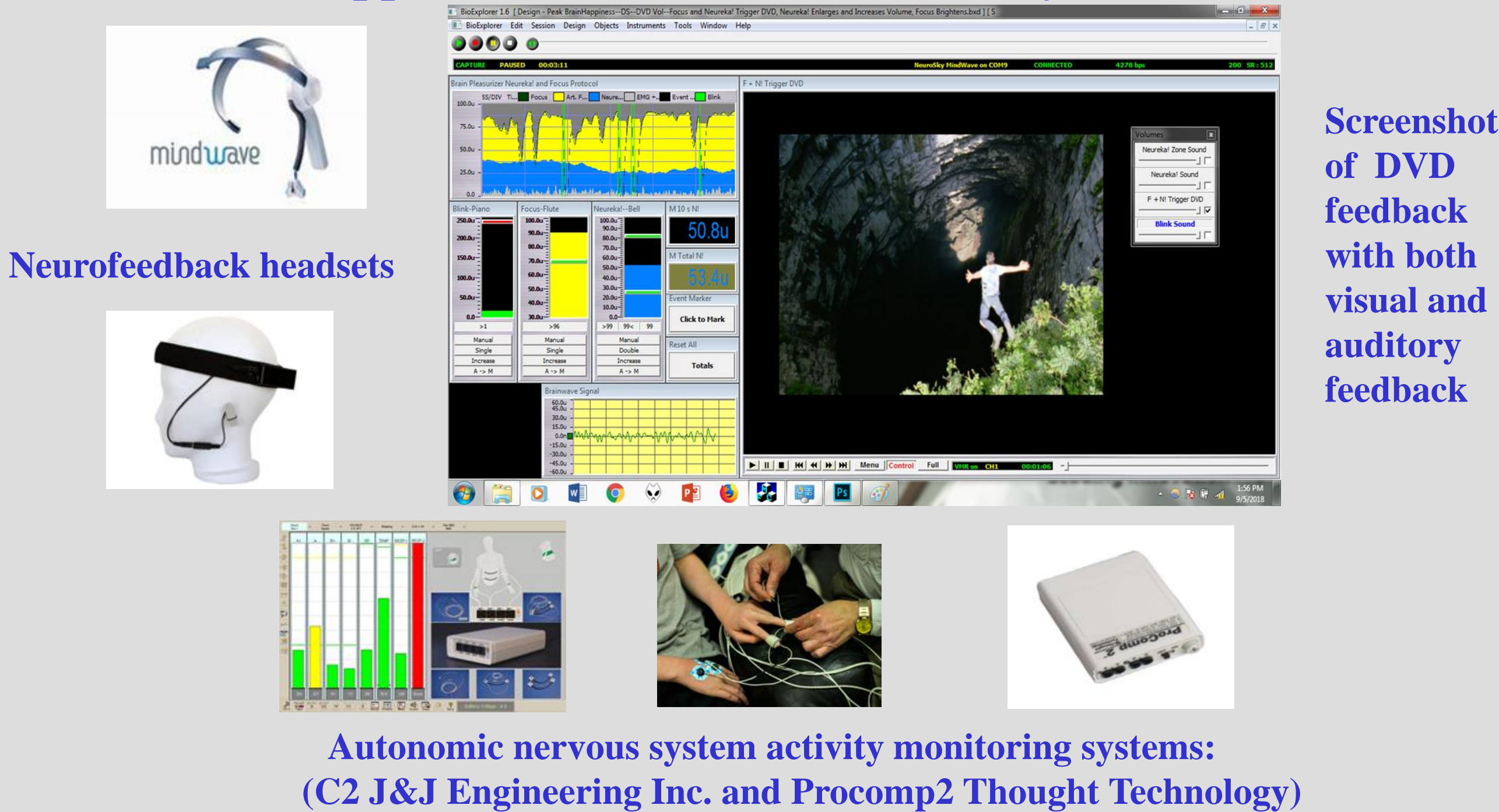
Aberrant Behavior Checklist (ABC) scores showed **Irritability** decrease from 13.20 ± 6.83 down to 7.30 ± 3.80 $df=1,18$, $F=5.61$, $p=0.029$ and **Hyperactivity** decrease from 21.40 ± 8.30 down to 14.10 ± 6.65 , $df=1,18$, $F=4.71$, $p=0.044$. **Achenbach's ASEBA** showed **Attention deficits** scores decrease from 70.91 ± 5.17 down to 65.36 ± 5.84 , $df=1,20$, $F=5.57$, $p=0.029$, and **Conduct behavior** scores decrease from 61.64 ± 6.39 down to 56.18 ± 4.68 , $df=1,20$, $F=5.21$, $p=0.034$. **SRS-2 questionnaire** post-training showed **T-score** decrease from 84.50 ± 8.66 down to 4.10 ± 11.13 , $df=1,20$, $F=5.46$, $p=0.031$.

Linear regression of heart rate and LF/HF of HRV



Method: Equipment

Peak Brain Happiness Trainer neurofeedback system (Goshen, KY)



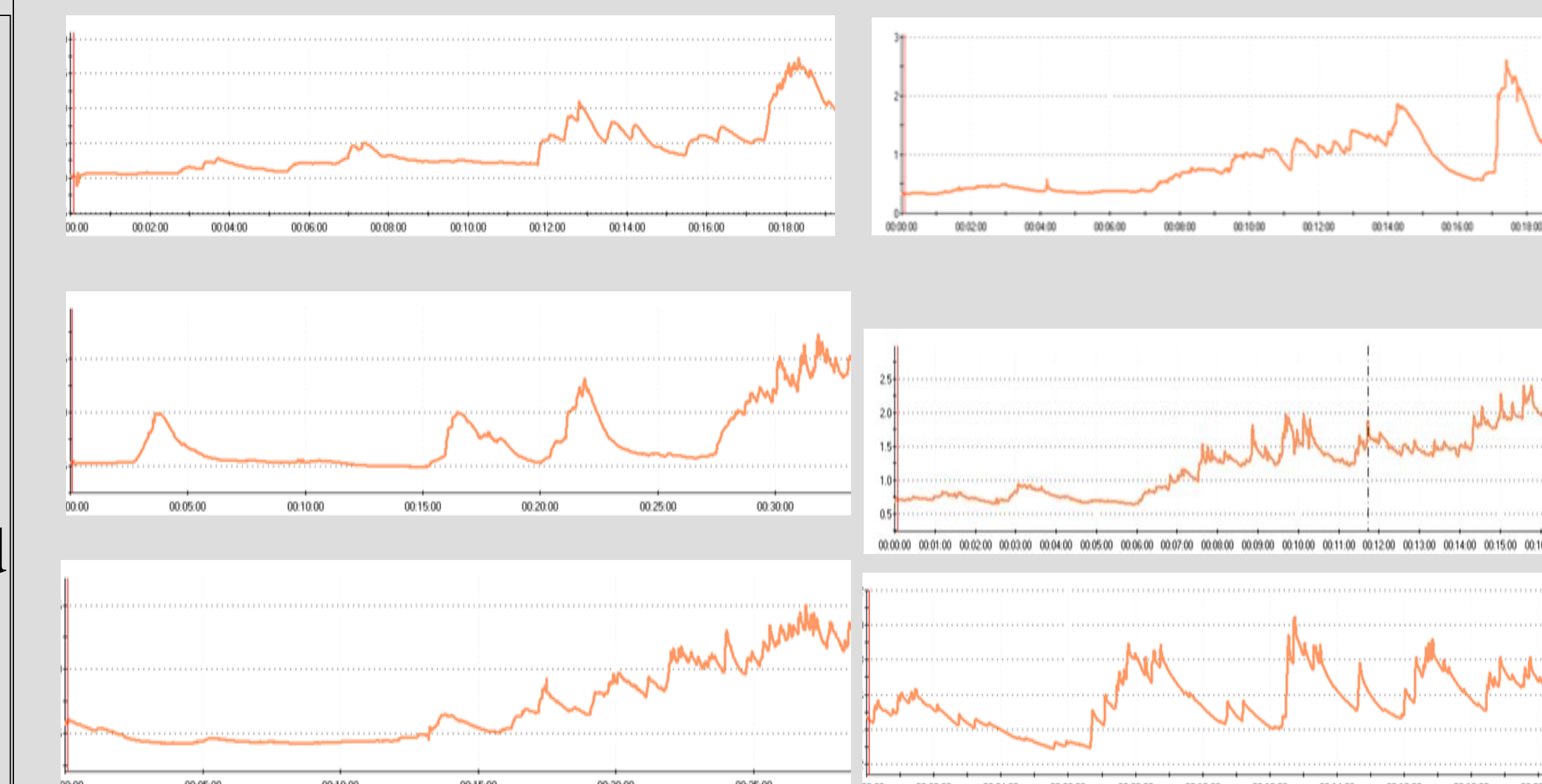
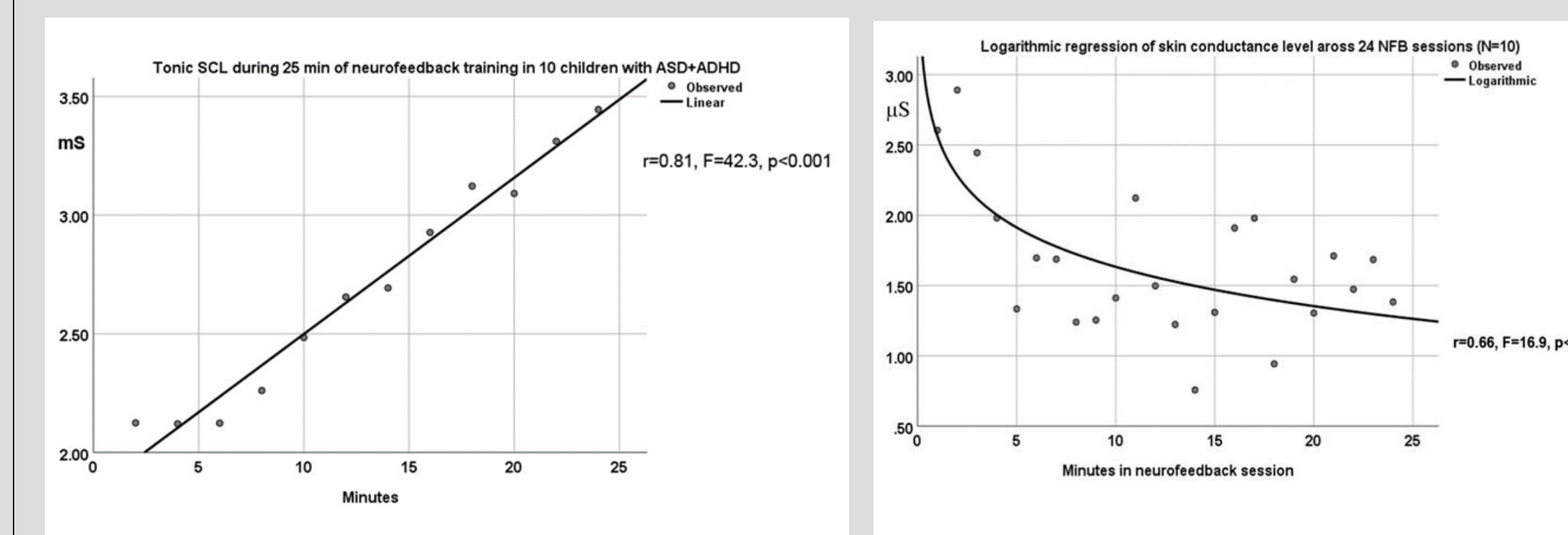
Autonomic nervous system activity monitoring systems: (C2 J&J Engineering Inc. and Procomp2 Thought Technology)

Subjects in this study

- Ten children were enrolled in this pilot study (mean 10.3 years, SD= 1.93, 7 boys, 3 girls, 24 sessions of neurofeedback each)
- Participants were recruited through the Developmental-Behavioral Unit of the GHS Pediatrics Outpatient Clinic, Department of Pediatrics, GHS (now Prisma Health), Greenville, and other referral sources in Greenville county.
- Diagnosis was made according to DSM-5 and further ascertained with the Autism Diagnostic Interview – Revised (ADI-R) or ADOS-2 and ADHD diagnosis was confirmed by medical records.
- All participants were high-functioning persons with autism diagnosis and had full-scale IQ > 70 assessed using WISC-IV.
- All 10 children had ADHD diagnosis as a comorbid condition.
- All GHS IRB-approved consent/assent forms were signed by participants and their parents/guardians.

Linear regression of SCL and raw SCL

Autism +ADHD group (N=10, 24 sessions of neurofeedback), linear regression during neurofeedback sessions and across the course raw and example of SCL changes during sessions.



Examples of raw SCL increases by the end of neurofeedback session in six subjects

Acknowledgement: This pilot study was funded by GHS HSC Transformative Research Grant and was intended to collect pilot data for clinical trial grant proposal to NIH.

Summary

- Neurofeedback training aimed at enhancement of the "Focused Attention" and "40 Hz-centered gamma" indices in autism +ADHD was accompanied by improved in *Hyperactivity* and *Irritability* by the Aberrant Behavior Checklist (ABC) inventory. Achenbach's ASEBA showed improvements in *Attention Problems/Deficits Scores* and *Conduct Behavior*. SRS-2 showed improvements in *T-score*.
- Self-regulation of prefrontal EEG measures of "Focused Attention" ("InhibitAll" protocol) 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 spectrum disorder with co-occurring ADHD.
- Twenty four 25 min long sessions of neurofeedback were sufficient to achieve ability to control EEG parameters of interest as evidenced by increase of theta/beta ratio and gamma power targets during training sessions.
- During 20-25 min of individual neurofeedback sessions we found linear increase of electrodermal activity (SCL), decrease of heart rate and several heart rate variability (HRV) measures improvements.

References

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 Achenbach, T. M., & Rescorla, L. A. (2012). *Multicultural guide for the ASEBA forms and profiles for ages 1½-18* (2nd ed.). Burlington, VT: University of Vermont.
 Constantino, J. & Gruber, S. (2012) *SRS-2*, Torrance, CA, WPS