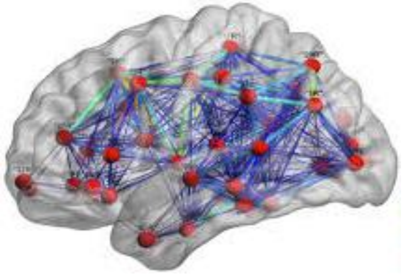


Advances in Coherence Based Neurofeedback Training

Robert Coben, PhD., Neuropsychologist, Co-Director, Integrated Neuroscience Services

Bendat, J. S., & Piersol, A. G. (1971). Random data: analysis and measurement procedures, John Wiley and Sons. *New York*.

Otnes, R. K., & Enochson, L. (1972). *Digital time series analysis*. John Wiley & Sons, Inc..

$$\gamma^2_{xy}(f) = \frac{|G_{xy}(f)|^2}{G_x(f)\, G_y(f)}$$

Gxy(f) is the cross-spectral density between x and y and Gx(f) and Gy(f) are the autospectral density of x and y respectively.

frontiers in Human Neuroscience

Front Hum Neurosci. 2014; 8: 45.
Published online 2014 Feb 26. doi: 10.3389/fnhum.2014.00045

PMCID: PMC3935255
PMID: 24616679

Using quantitative and analytic EEG methods in the understanding of connectivity in autism spectrum disorders: a theory of mixed over- and under-connectivity

Robert Coben,[1,2,*] Iman Mohammad-Rezazadeh,[3,4] and Rex L. Cannon[5]

$$\tau_{xy}^2(f) = \frac{(\mathbf{G}_{xy}(f))^2}{(\mathbf{G}_{xx}(f)\mathbf{G}_{yy}(f))} \quad (1)$$

Where: $G_{xy}(f)$ = cross power spectral density and

$G_{xx}(f)$ and $G_{yy}(f)$ = auto power spectral densities

The final normalized coherence value is given by Equation (2):

$$\tau_{xy}^2(f) = \frac{\mathbf{r}_{xy}^2 + \mathbf{q}_{xy}^2}{\mathbf{G}_{xx}\mathbf{G}_{yy}} \quad (2)$$

Where: $r^2{}_{xy}$ = real cospectrum and $q^2{}_{xy}$ = imaginary quadspectra

$G_{xx}(f)$ and $G_{yy}(f)$ = as in Equation (1)

Phase: ***159.1549 tan − 1(q/r)/fc***

Where: ***r*** and ***q*** = as in Eq.2; ***fc*** = center frequency of filter

$$COHERENCE = \frac{|H_{xy}|^2}{|H_{xx}|\,|H_{yy}|}$$

Sometimes referred to as pure coherence as it is independent of phase and amplitudes.

$$SPECTRALCORRELATION = \frac{\left(\sum |X_f|\,|Y_f|\right)^2}{\left(\sum |X_f|^2 \sum |Y_f|^2\right)}$$

Similarity of the FFT spectra regardless of phase.

$$COMODULATION = \frac{\left(\sum |X_t|\,|Y_t|\right)^2}{\left(\sum |X_t|^2 \sum |Y_t|^2\right)}$$

Similarity of amplitudes across time.

$$SIMILARITY_{[A,B]} = \frac{2AB}{A^2 + B^2}$$

Variation in amplitude and phase. Sometimes referred to as synchrony.

$$PHASE = Arc\tan\left(\frac{b}{a}\right)$$

- Different approaches to neurofeedback have used all of these approaches
- Coherence has received the most attention due to it's pureness of measurement (not without it's problems)
- Virtually every neurofeedback systems allows you to do coherence training between pairs of sites, some do comodulation (EEGer etc.) and others synchrony

Coherence training as a new form of Neurofeedback first began about 18 years ago.

- The originators included Joseph Horvat, Jonathan Walker and Kirt Thornton.
- All of them started these attempts with persons with closed head injuries.
- Horvat and Walker used coherence training and Thornton spectral correlation (even though it is called coherence on the Lexicor machine)

Improvement/Rehabilitation of Memory Functioning with Neurotherapy/QEEG Biofeedback

Kirtley Thornton, PhD *J Head Trauma Rehabil* 2000;15(6):1–13

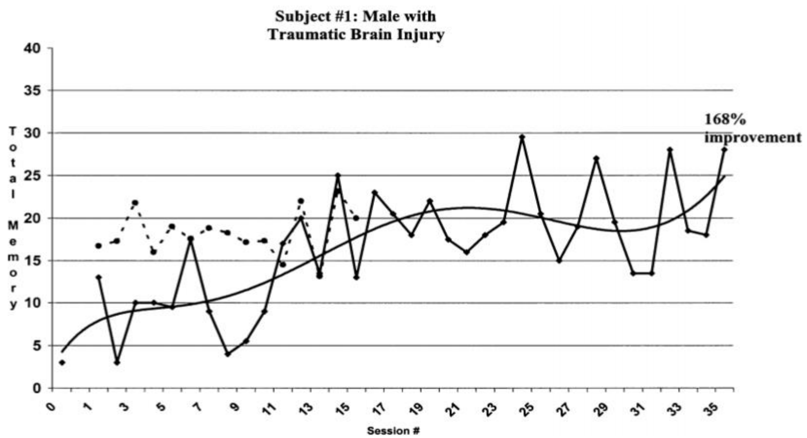


Fig 1. Undulating curve is a best-fit polynomial trend line to the 6th order. Dotted line = norms; Solid line = subject.

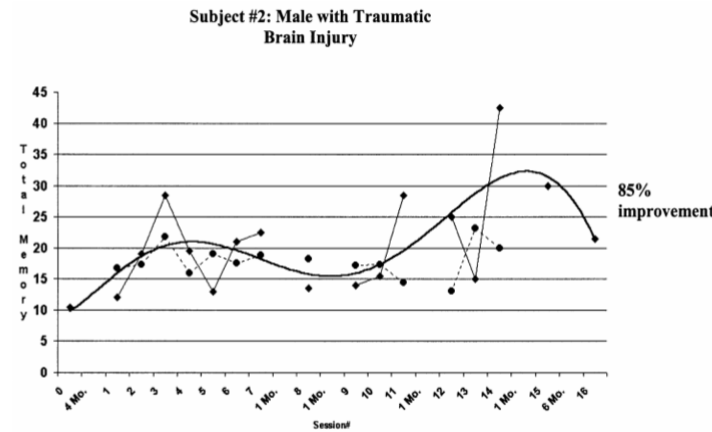


Fig 2. Undulating curve is a best-fit polynomial trend line to the 6th order. Dotted line = norms; Solid line = subject.

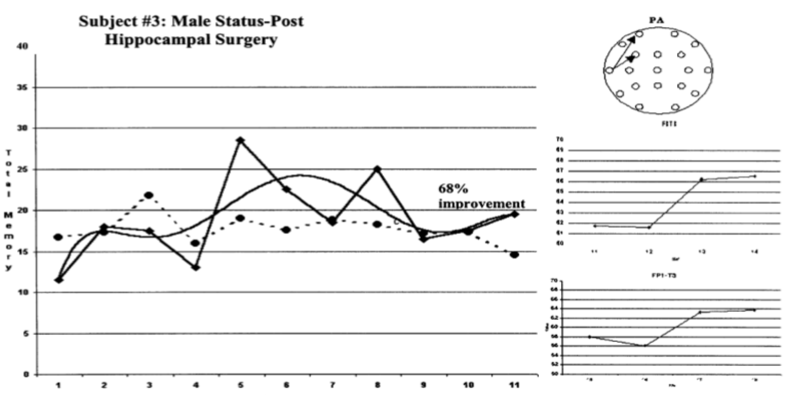


Fig 3. Undulating curve is a best-fit polynomial trend line to the 6th order. Dotted line = norms; Solid line = subject; PA = phase alpha.

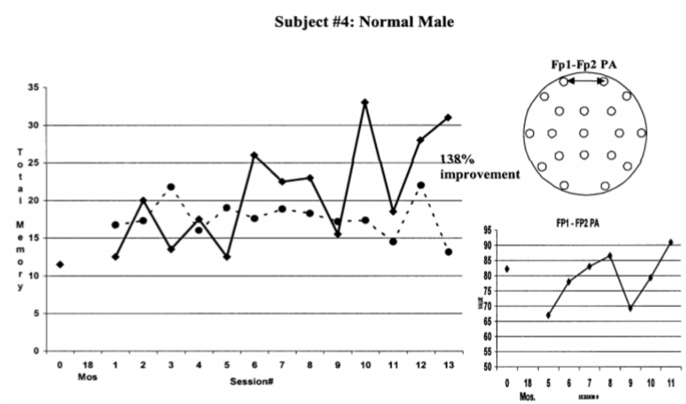


Fig 4. Undulating curve is a best-fit polynomial trend line to the 6th order. Dotted line = norms; Solid line = subject; PA = phase alpha.

Impact of qEEG-Guided Coherence Training for Patients with a Mild Closed Head Injury

Jonathan E. Walker, MD
Charles A. Norman, PhD
Ronald K. Weber, PhD

Journal of Neurotherapy, Vol. 6(2) 2002

TABLE 3. Electrode Placement for Coherence Scores

Intrahemispheric	Interhemispheric
Fp1/F3	Fp1/Fp2
Fp2/F4	F3/F4
T3/T5	F7/F8
T4/T6	C3/C4
C4/P4	T5/T6
F3/O1	P3/P4
F4/O2	O1/O2

TABLE 4. Mean and Range for Age, Time Since MHI, Number of Sessions and Global Improvement

Factor	Mean Standard Deviation	Range
Age (yrs)	38.6 ± 13.5	15-55
Time Since MHI (months)	12.7 ± 18.5	3-70
Number of Sessions	19.1 ± 9.7	5-40
Global Improvement	72.7 ± 27.6	0-100

Thornton’s work has focused on TBI and Reading Disability

Traumatic Brain Injury Rehabilitation: QEEG Biofeedback Treatment Protocols

Kirtley E. Thornton · Dennis P. Carmody

Appl Psychophysiol Biofeedback (2009) 34:59–68
DOI 10.1007/s10484-009-9075-4

Electroencephalogram biofeedback for reading disability and traumatic brain injury

Kirtley E. Thornton, PhD[a,*], Dennis P. Carmody, PhD[b]

Child Adolesc Psychiatric Clin N Am
14 (2005) 137–162

Activation conditions

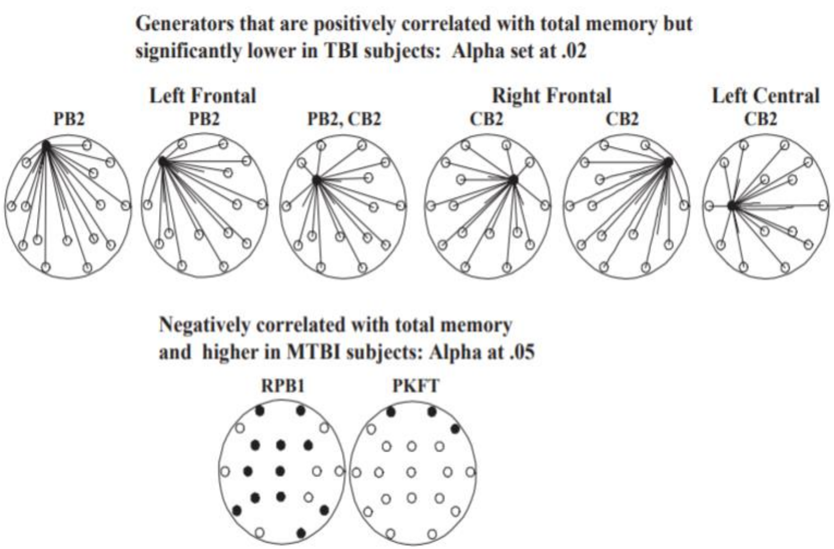


Fig. 3. Normal Vs traumatic brain injury: listening-to-paragraphs TBI (n = 80; normal = 49). PB2, phase beta 2; CB2, coherence beta 2; RPB1, relative power beta 1; PKFT, peak frequency theta; beta 1, 13–32 Hz; beta 2, 32–64 Hz.

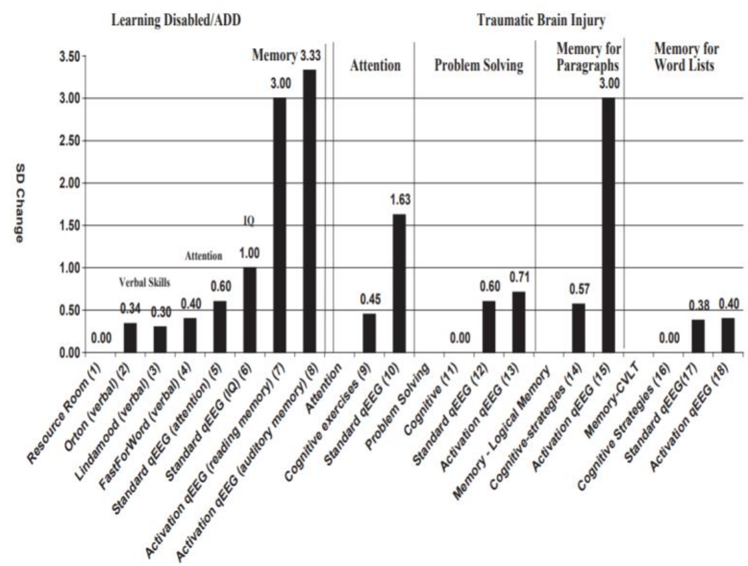


Fig. 7. SD changes in learning disability and subjects with TBI across different intervention modes and different cognitive abilities. The following numbers, which follow the treatment type listed in the figure, draw their values from the reference number in brackets. 1 [75], 2 [21], 3 [22], 4 [23], 5 [50,67,76], 6 [51–54], 8 [73,74], 9 [77], 10 [63,67], 11 [67,77], 12 [67], 14 [77], 15 [73,74], 16 [77], 17 [71].

A Modular Activation/Coherence Approach to Evaluating Clinical/QEEG Correlations and for Guiding Neurofeedback Training: Modular Insufficiencies, Modular Excesses, Disconnections, and Hyperconnections

Jonathan E. Walker, MD
Gerald P. Kozlowski, PhD
Robert Lawson, MS

Journal of Neurotherapy, Vol. 11(1) 2007

Coherence	Result of Hypocoherence	Result of Hypercoherence
1) FP1/FP2	**Less efficient integration of** logical/emotional attention	**Lack of flexibility** in integrating logical/emotional attention
2) FP1/F7	logical attention/verbal expression	Lack of flexibility in integrating logical attention/verbal expression
3) FP1/F3	logical attention/RUE motor actions	Lack of flexibility of logical attention/RUE motor actions
4) FP1/FZ	logical attention/midline motor actions	Lack of flexibility of logical attention/midline motor actions
5) FP1/F4	logical attention/LUE motor actions	Lack of flexibility of logical attention/LUE motor actions
6) FP1/F8	logical attention/emotional expression	Lack of flexibility of logical attention/emotional expression

- Modular insufficiencies (location)
- Diffuse insufficiencies
- Modular excesses
- Diffuse excesses
- Disconnections
- Hyperconnections

Neurofeedback treatment of epilepsy

Jonathan E. Walker, MD[a,b,*], Gerald P. Kozlowski, PhD[a,b]

Child Adolesc Psychiatric Clin N Am
14 (2005) 163–176

The Neurophysiology of Dyslexia: A Selective Review with Implications for Neurofeedback Remediation and Results of Treatment in Twelve Consecutive Patients

Jonathan E. Walker, MD
Charles A. Norman, PhD

Journal of Neurotherapy, Vol. 10(1) 2006

TABLE 1. Effect of Neurofeedback in Improving Reading Level in 10 Additional Cases

			Pre-Neurofeedback		Post-Neurofeedback
Case	Age	Grade	Reading Grade Level	Neurofeedback Protocols (5 sessions each)	Reading Grade Level
3	16	10	9	↓ 2-7 Hz/↑ 12-15 Hz at FP2	12
				↓ 1-8 Hz plus ↓ 18-30 Hz at OZ	
				↓ coherence of beta at P3/O1	
				↓ coherence of beta at FP2/O2	
				↑ coherence of delta at F3/O1	
				↑ coherence of theta at C4/P4	
				↑ coherence of delta at F4/O2	

Clinical EEG and Neuroscience

Power Spectral Frequency and Coherence Abnormalities in Patients with Intractable Epilepsy and Their Usefulness in Long-Term Remediation of Seizures Using Neurofeedback

Jonathan E. Walker, M.D

First Published October 1, 2008 | Research Article

Following our previous study in 2005, we report an additional 25 patients so treated. We also report an analysis of the frequency of QEEG abnormalities in this patient group. All of the intractable epileptic patients had one or more slow foci (excessive theta or delta compared with the normal database). One third had a relative deficiency of beta power. One fourth had a deficiency of absolute delta. Eighteen percent had excessive absolute alpha power, 18% had deficient absolute alpha power, 18% percent had excessive absolute beta power, and 18% percent had deficient absolute beta power. Hypocoherence of theta was found in 75%, and decreases in alpha coherence were noted in 42%. Hypocoherence of beta was found in 50%, and hypocoherence of delta was found in 25%. Increases in alpha coherence were noted in 33%. Seventeen percent had no coherence abnormalities.

When most of the power and coherence abnormalities were normalized with neurofeedback training, all the patients became seizure-free; 76% no longer required an anticonvulsant for seizure control.

Neurofeedback training of alpha-band coherence enhances motor performance

Anais Mottaz, Marco Solcà, Cécile Magnin, Tiffany Corbet, Armin Schnider, Adrian G. Guggisberg *

Clinical Neurophysiology

Clinical Neurophysiology xxx (2014) xxx–xxx

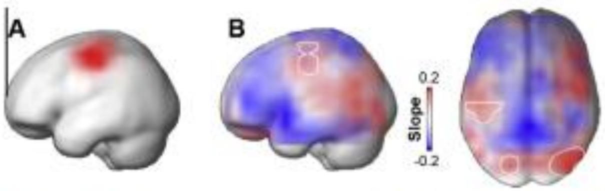
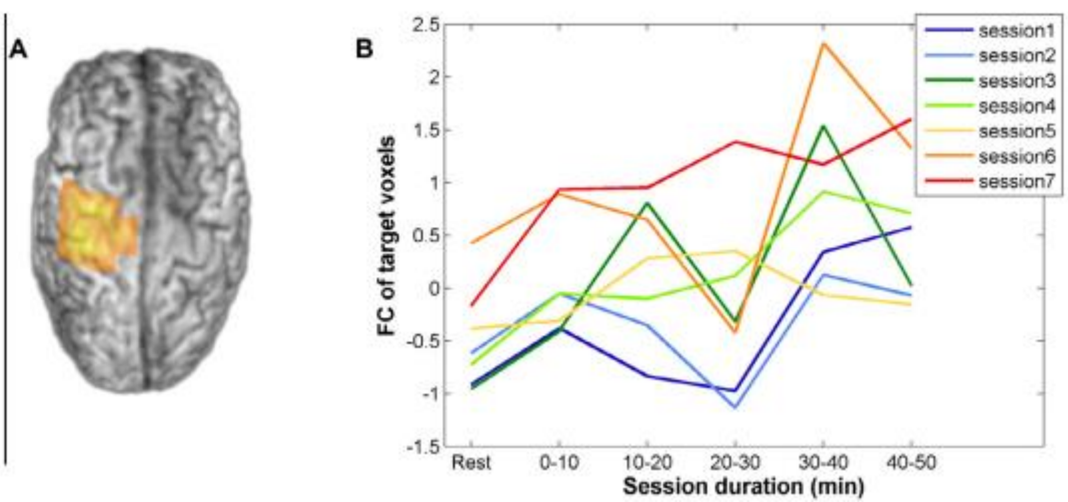


Fig. 2. Mean slope of alpha-band coherence evolution during neurofeedback training of 10 healthy subjects. Subjects tried to voluntarily enhance alpha-band coherence between the left or right hand motor cortex and the rest of the brain in a single session. Subjects with right target are flipped to left for visualization. (**A**) The target area is marked in red. (**B**) Red color indicates regions which global alpha-band coherence increase during the feedback session, blue regions which coherence decrease. Increases occurred relatively specifically in the target area. Maps are unthresholded, significant areas ($p < 0.05$, uncorrected) are marked with white contour lines. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Clinical assessment of sensorimotor function of the right upper limb in the patient.

	3 Days before training	1 Day after training	6 Weeks after training
Motor assessment			
Upper limb Fugl-Meyer Assessment	37/66	44/66	45/66
Jamar	11.5 kg	11 kg	10 kg
Nine Hole Peg Test	0 pegs placed in 2 min	6 pegs placed in 2 min	7 pegs placed in 2 min
Somatosensory assessment			
Pressure perception (nylon filament)			
D1 pulp	0.6 g	0.4 g	0.4 g
D2 pulp	0.4 g	0.4 g	0.4 g
Hypothenar	0.6 g	0.4 g	0.4 g
Forearm	0.6 g	0.6 g	0.6 g



The Effectiveness of Neurofeedback Training on EEG Coherence and Neuropsychological Functions in Children With Reading Disability

Mohammad Ali Nazari[1], Elnaz Mosanezhad[1], Tooraj Hashemi[1], and Ali Jahan[1,2]

Clinical EEG and Neuroscience 2012
43(4) 315-322

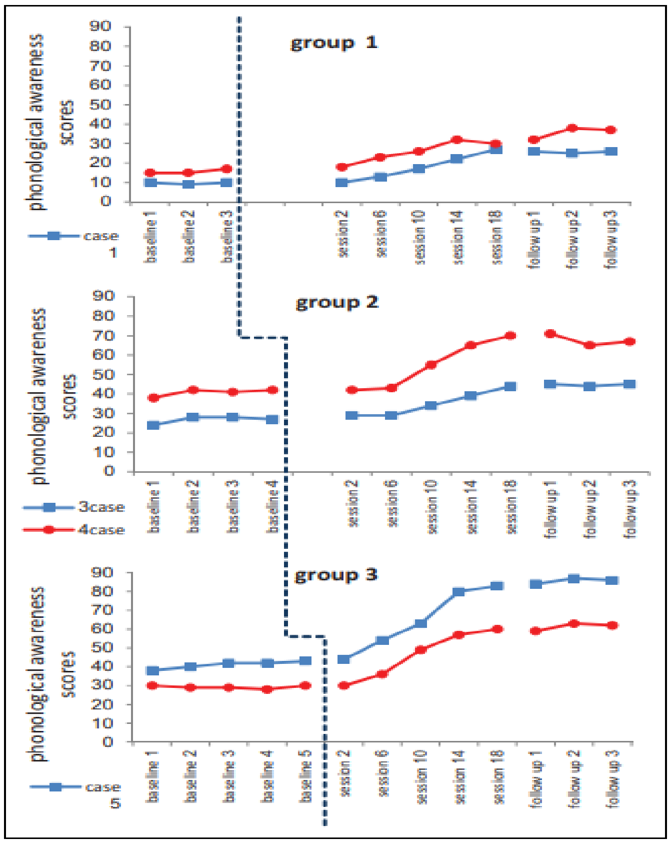


Figure 2. Phonological awareness scores across baseline, treatment, 1-week, 1-month, and 2-month follow-up assessments conducted for all 3 groups.

Table 4. Z Scores FFT Coherence for Pre- and Posttreatment

	Delta (1-4 Hz)		Theta (4-8 Hz)		Beta (12-25 Hz)					
	Fz-Cz pre	Fz-Cz post	T3-T4 Pre	T3-T4 Post	Fz-Cz pre	Fz-Cz Post	Cz-Pz pre	Cz-Pz Post	Cz-C4 Pre	Cz-C4 Post
Case 1	−2.33	0.98	2.38	1.12	−3.94	0.49	−2.69	−0.2	−2.55	0.98
Case 2	−3.40	−1.89	2.41	−0.80	−4.94	−1.76	−3.6	0	−4.16	−1.13
Case 3	−2.95	−0.14	2.85	−0.16	−3.89	−0.82	−3.06	−0.99	−3.28	−0.1
Case 4	−3.68	0.77	3.11	−0.63	−7.17	0.94	−3.69	0.25	−3.72	0.01
Case 5	−4.13	−0.62	1.01	−0.38	−6.28	−2.33	−2.78	−0.38	−4.97	−1.86
Case 6	−1.77	0.75	2.06	0.62	−3.62	−0.47	−2.57	−0.05	−2.29	0.1
Mean	−3.043	−0.025	2.303	−0.038	−4.973	−0.658	−3.065	−0.228	−3.495	−0.333

The Impact of Coherence Neurofeedback on Reading Delays in Learning Disabled Children: A Randomized Controlled Study

Robert Coben[1], Emma Kate Wright[2], Scott L. Decker[2], and Tina Morgan[3]*

www.neuroregulation.org Vol. 2(4):168–178 2015 doi:10.15540/nr.2.4.168

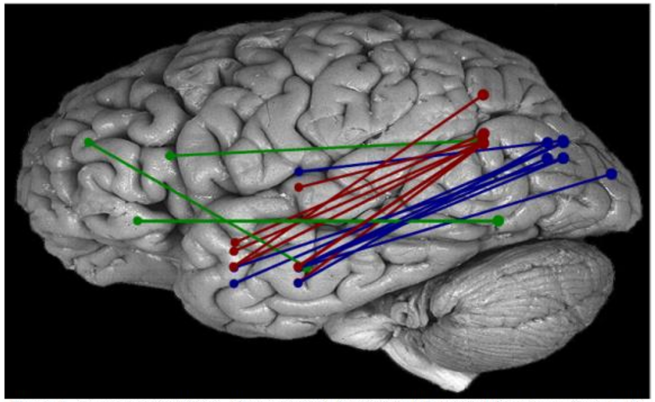


Figure 1. Graphic representation of two-channels involved in NF protocol for each subject in the experimental group. Represented are those trained from occipital-temporal (blue), parietal-temporal (red), and temporal-parietal-frontal (green).

Table 2

Reading delay in years for the total sample, experimental (coherence) and control (resource) groups.

Descriptives

						95% Confidence Interval for Mean			
		N	Mean	*SD*	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Reading Delay	Coherence	21	3.220	1.1422	.2492	2.700	3.739	1.6	5.3
	Resource	21	2.697	0.6073	.1325	2.421	2.974	1.9	4.1
	Total	42	2.958	0.9414	.1453	2.665	3.252	1.6	5.3

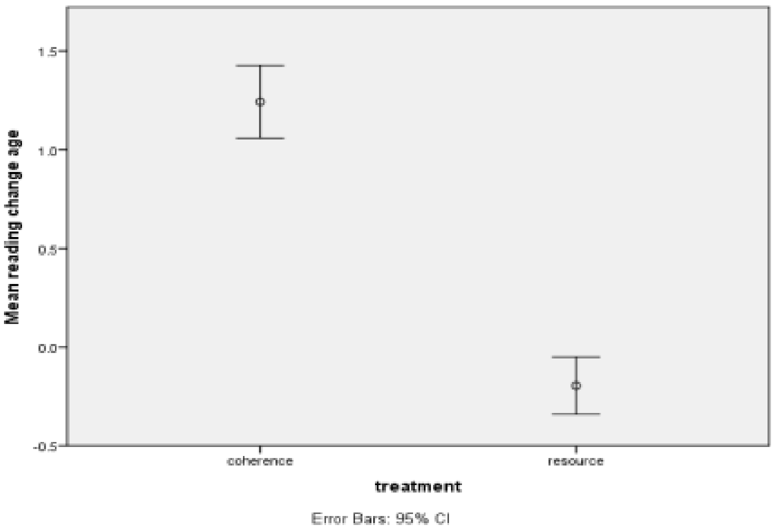


Figure 2. Change in age equivalent reading scores by group.

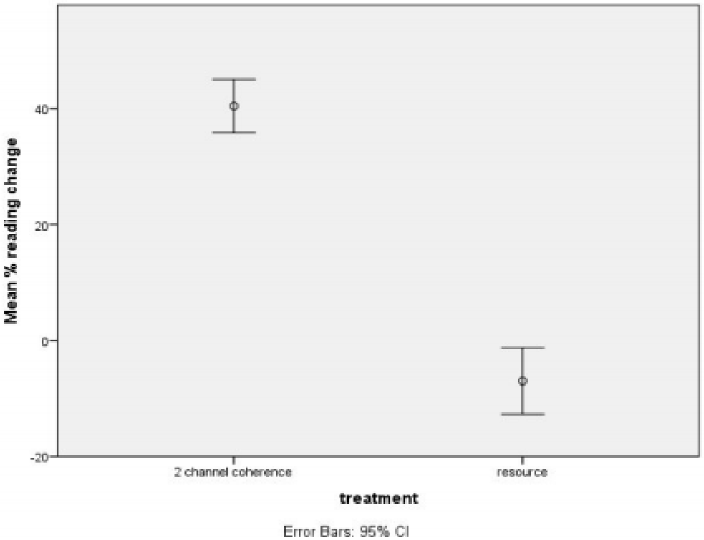


Figure 3: Change in percentage reading delay by group.

Improvements in Spelling after QEEG-based Neurofeedback in Dyslexia: A Randomized Controlled Treatment Study

Marinus H. M. Breteler · Martijn Arns · Sylvia Peters · Ine Giepmans · Ludo Verhoeven

Appl Psychophysiol Biofeedback (2010) 35:5–11
DOI 10.1007/s10484-009-9105-2

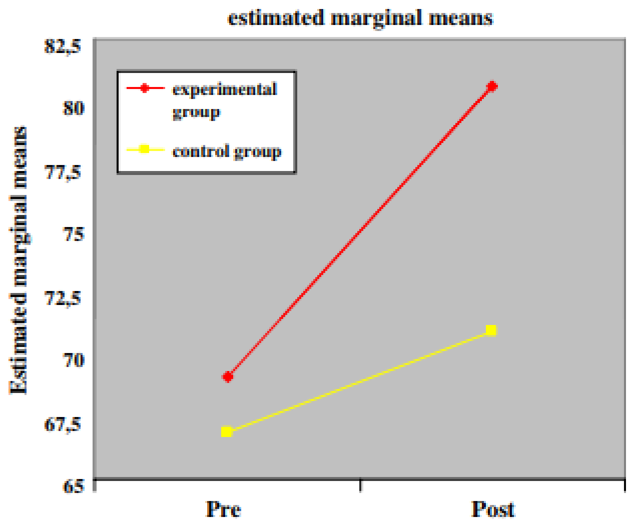
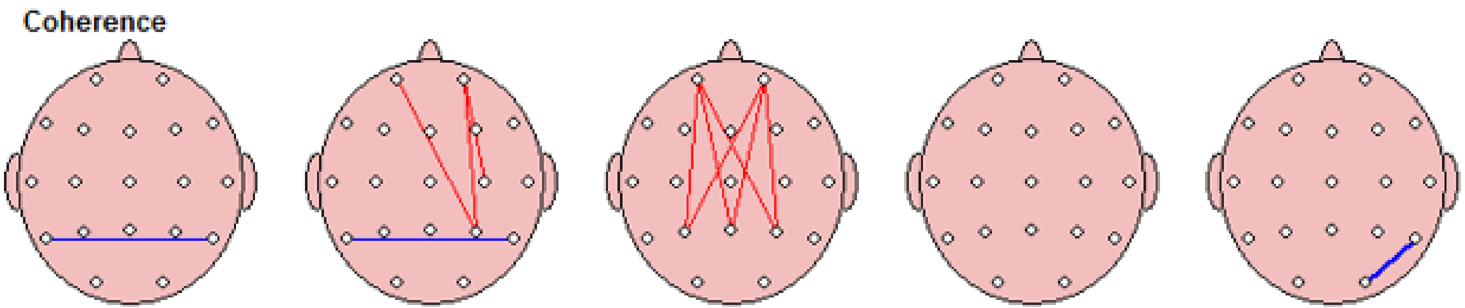


Fig. 1 Pre- and posttest scores on spelling test

Table 2 Specification of personalized neurofeedback training protocols and their effect on spectral power and coherence

Gender, age	Power protocol	Coherence protocol	Power pre vs. post (Z-scores)	Coherence pre vs. post (Z-scores)
1		T3–T4 delta down EO		1.24 vs. 1.01
Boy age 8				
2	T6 2–5 Hz down	F7–C3 beta down EC	Theta/beta	1.67 vs. −0.20
Boy age 11	15–20 up EC		1.97/−0.54 vs. 0.87/−0.96	
3		T3–T4 delta down EO		3 vs. ?
Girl age 10		F7–C3 beta down EO		2.59 vs. ?
				no 2nd measurement
4	T6 2–12 Hz down EO	F7–FC3 alpha down EO	Delta/theta/alpha	0.92 vs. ?
Boy age 10			3.93/2.29/2.27	no EO data 2nd measurement
			no EO data 2nd measurement	
5	T4 2–8 Hz down EO	T3–T4 delta down EO	Delta/theta	3 vs. −0.02
Girl age 10		F7–FC3 alpha down EO	2.27/1.62 vs. 0.45/0.13	1.56 vs. −0.40
6		T3–T4 delta down EO		4.94 vs. 0.61
Boy age 9		F7–C3 alpha down EO		1.71 vs. −0.58
7	T6 2–5 Hz down	T3–T4 delta down EO	Delta	1.79 vs. −1.03
Girl age 8	Beta up EO	F7–C3 beta down EO	1.34 vs. −0.04	2.21 vs. −0.37
8	Fz 18–20 Hz down		Beta/alpha	
Boy age 12	5–8 Hz down EC		1.42/−1.42 vs. 0.32/−1.44	
	C3 12–15 Hz up EO			
9		F7–C3 beta down EO		1.82 vs. 1.07
Boy age 9				
10	F3 2–4 Hz down	T3–T4 delta down EO	1.55 vs. 1.16	2.04 vs. 1.49
Boy age 8		F7–FC3 alpha down EO		3.55 vs. 1.30

Processing of Coherence Data



Assessment-Guided Neurofeedback for Autistic Spectrum Disorder

Robert Coben, PhD
Ilean Padolsky, PhD

Journal of Neurotherapy, Vol. 11(1) 2007

TABLE 2. Demographics of Neurofeedback Group

Age	Gender	Race	Handedness	Number of Meds	Total ATEC Score
Mean 8.92 years	31 Males	36 Caucasian	27 Right	22 None	Mean 45.161
	6 Females	1 Asian-American	5 Left	8 One	
Range 3.92-14.66 years			5 Mixed	5 Two	Range 12-100
				2 Three	

Note. Total ATEC Score was computed from the Autism Treatment Evaluation Checklist (ATEC; Rimland & Edelson, 2000).

TABLE 3. Demographics of Control Group

Age	Gender	Race	Handedness	Number of Meds	Total ATEC Score
Mean 8.19 years	10 Males	12 Caucasian	9 Right	8 None	Mean 45.25
	2 Females		2 Left	2 One	
Range 5.83-10.92 years			1 Mixed	1 Two	Range 20-72
				1 Three	

Note. Total ATEC Score was computed from the Autism Treatment Evaluation Checklist (ATEC; Rimland & Edelson, 2000).

TABLE 7. Percent Ratings for Neurofeedback Group

Initial Total ATEC Range= 28.000-56.500	**%ile 9^{th}-39^{th}%ile**	**Severity Mild-Moderate**
Pre-ATEC Total Mean=46.100	**Post-ATEC Tot al Mean=27.733**	**Significance (p) p < .000**
Pre-GADS ADQ Mean=83.852	**Post-GADS ADQ Mean=72.519**	**Significance (p) p < .001**
Pre-BRIEF GEC Mean=71.700	**Post-BRIEF GEC Mean=64.767**	**Significanc (p) p < .003**
Pre-PIC-2 TOTC Mean=71.250	**Post-PIC-2 TOTC Mean=64.250**	**Significance (p) p < .006**

*Note. ATEC=Autism Treatment Evaluation Checklist; GADS ADQ=Gilliam Asperger's Disorder Scale Asperger's Disorder Quotient; BRIEF GEC=Behavior Rating Inventory of Executive Function Global Executive Composite; PIC-2 TOTC =Personality Inventory for Children Second Edition Total Composite

TABLE 8. Neuropsychological Testing* for Neurofeedback Group

Pre-Attention Mean z= -1.859	**Post-Attention Mean z=-0.571**	**Significance (p) p < .000**
Pre-Visual Perceptual Mean z= - 2.483	**Post-Visual Perceptual Mean z= -1.584**	**Significance (p) p < .000**
Pre-Executive Mean z= -1.818	**Post-Executive Mean z= -0.783**	**Significance (p) p < .001**
Pre-Language Mean z= -1.928	**Post-Language Mean z= -0.798**	**Significance (p) p=.000**

*Note. All neuropsychological testing consisted of composite scores for indices of attention, visual perceptual, executive, and language domains.

The Relative Efficacy of Connectivity Guided and Symptom Based EEG Biofeedback for Autistic Disorders

Robert Coben · Thomas E. Myers

Appl Psychophysiol Biofeedback (2010) 35:13–23

Table 4 Percent change per session

	N	Mean	SD	*t*	*df*	Sig. (2-tailed)
Speech/lang/comm						
Jarusiewicz (2002)	12	1.12	1.03	−3.092	22	0.005
Coben and Padolsky (2007)	12	2.83	1.62			
Sociability						
Jarusiewicz (2002)	12	1.01	1.06	−2.608	22	0.016
Coben and Padolsky (2007)	12	2.15	1.08			
Sens/cog awareness						
Jarusiewicz (2002)	12	.55	.37	−2.947	22	0.012
Coben and Padolsky (2007)	12	2.12	1.80			
Health/phys/behavior						
Jarusiewicz (2002)	12	.68	.74	−3.471	22	0.002
Coben and Padolsky (2007)	12	2.05	1.15			
Total						
Jarusiewicz (2002)	12	.84	.57	−4.471	22	0.000
Coben and Padolsky (2007)	12	2.31	.98			

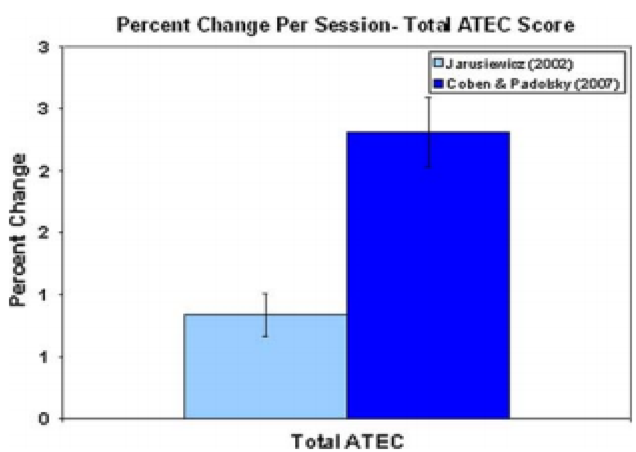


Fig. 5 The amount of change in Total ATEC scores per session was significantly greater in Coben and Padolsky (2007) than the amount of change per session in Jarusiewicz (2002)

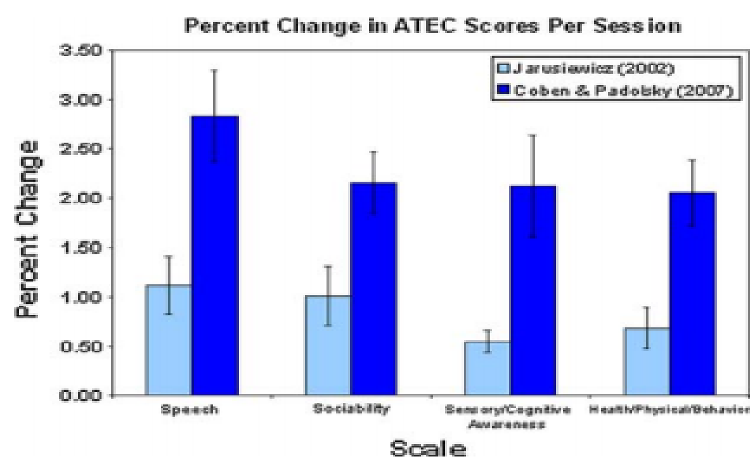


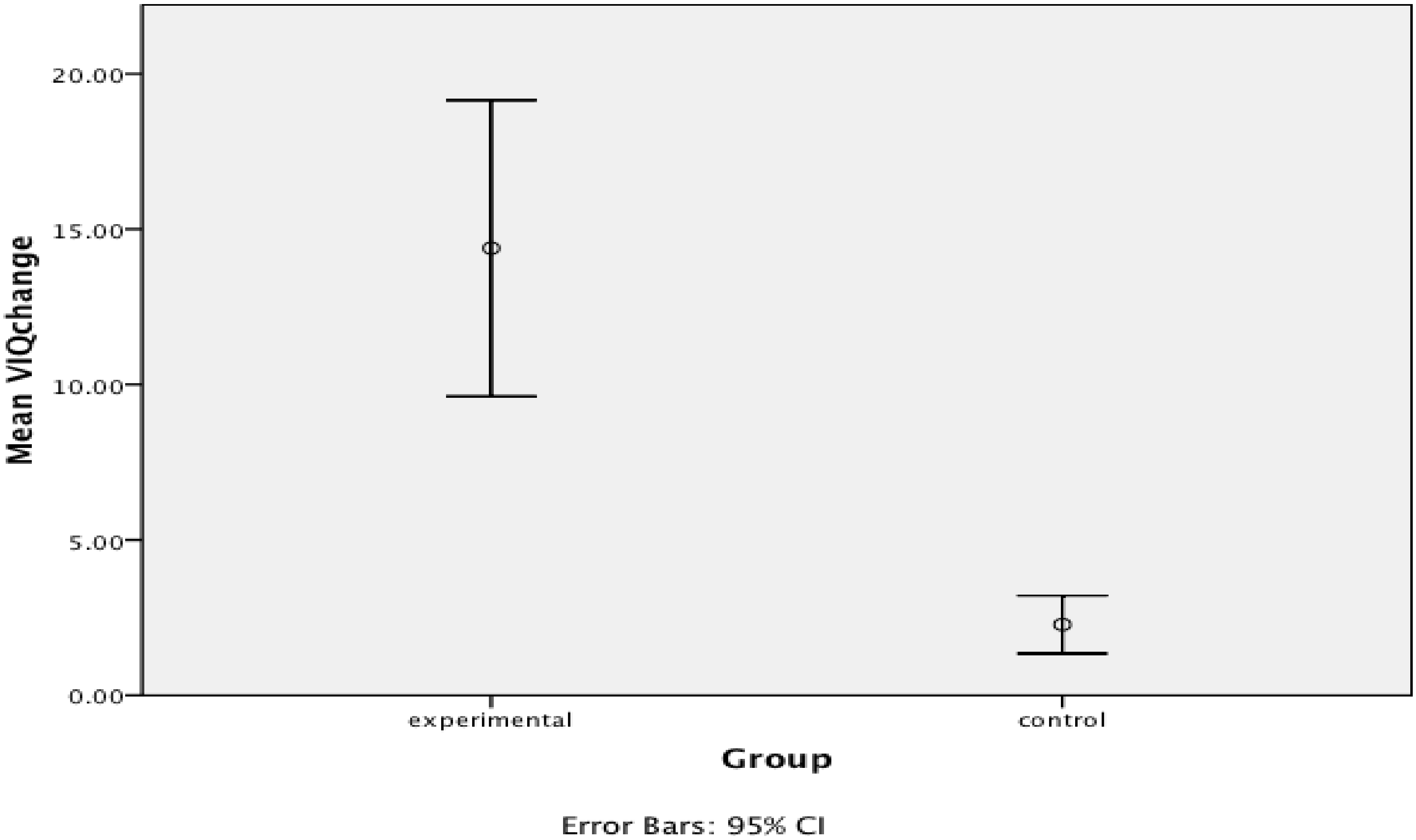
Fig. 4 The amount of change which occurred per session in Coben and Padolsky (2007) was significantly greater than the amount of change which occurred per session in Jarusiewicz (2002) for all subscales of the ATEC

Efficacy of Connectivity Guided Neurofeedback on Language Functions and Intelligence in Autism

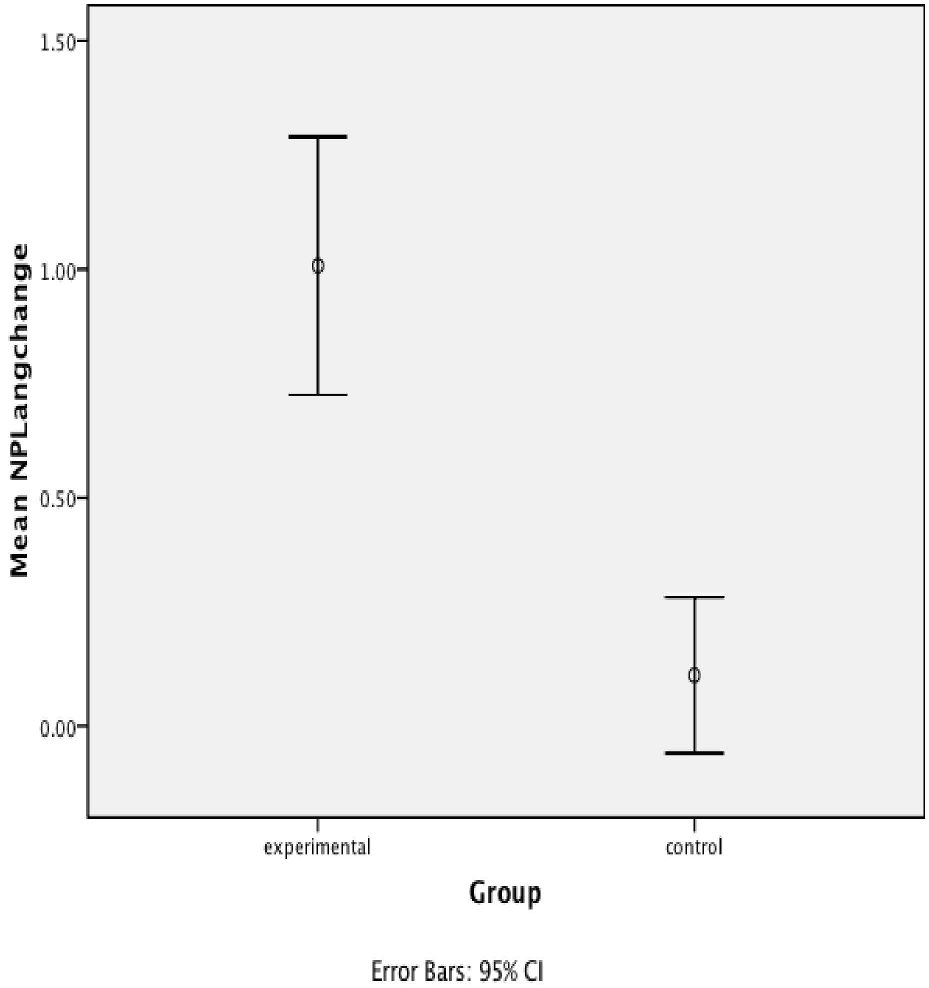
Robert Coben, Ph.D.[1], N. Kyle Jamison, B.S.[2], Nicholas Lofthouse, Ph.D.[2], Aishwarya Balasubramaniyan, B.S.[3], Elizabeth Hurt, Ph.D.[2], & L. Eugene Arnold, M.D., M.Ed.[2]
[1]**NeuroRehabilitation & Neuropsychological Services, NY**
[2]The Ohio State University Wexner Medical Center
[3]University of Illinois

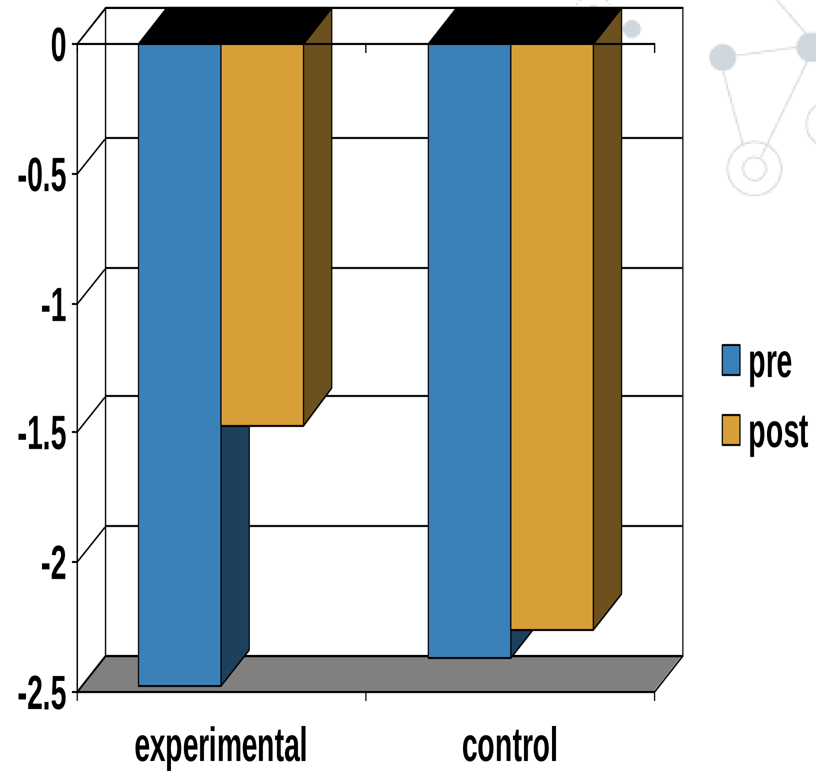
Abstract
Due to the limitations of current Autism Spectrum Disorder (ASD) treatment (Tx) options and established evidence for its neurological basis, specifically neural connectivity abnormalities, we examined the efficacy of neurofeedback (NF) training as a Tx for language deficits in autism. We administered up to 20 sessions of quantitative electroencephalography-(QEEG) guided NF coherence training, targeting the brain's language centers, to 18 children with autism. When compared to a waitlist control group of children with autism matched for age and IQ, significant improvements were found in measures of language, intelligence, and ratings of autistic behavioral symptoms. Pending further research, NF may be considered an effective Tx option to improve language functioning in those with autism.

Verbal IQ Change



Language change

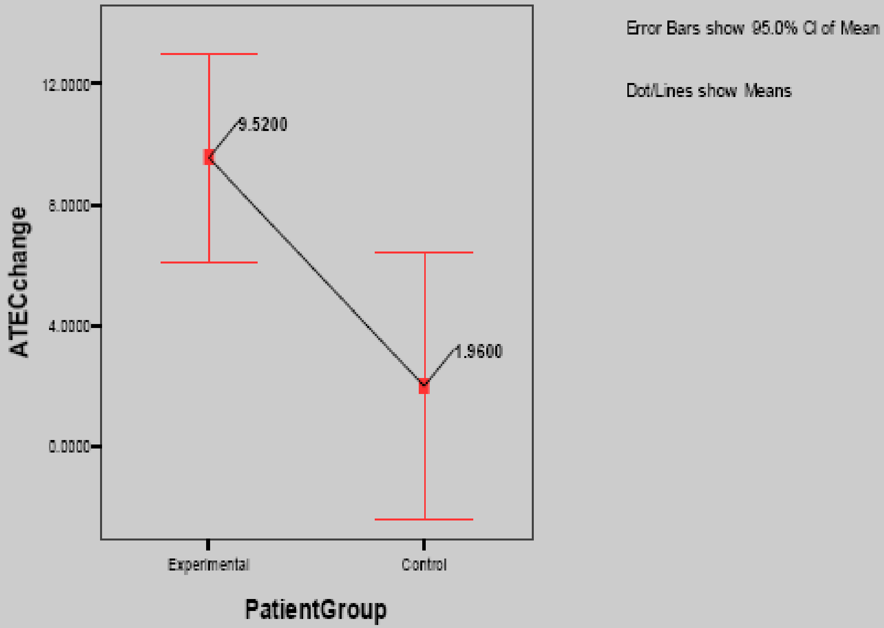


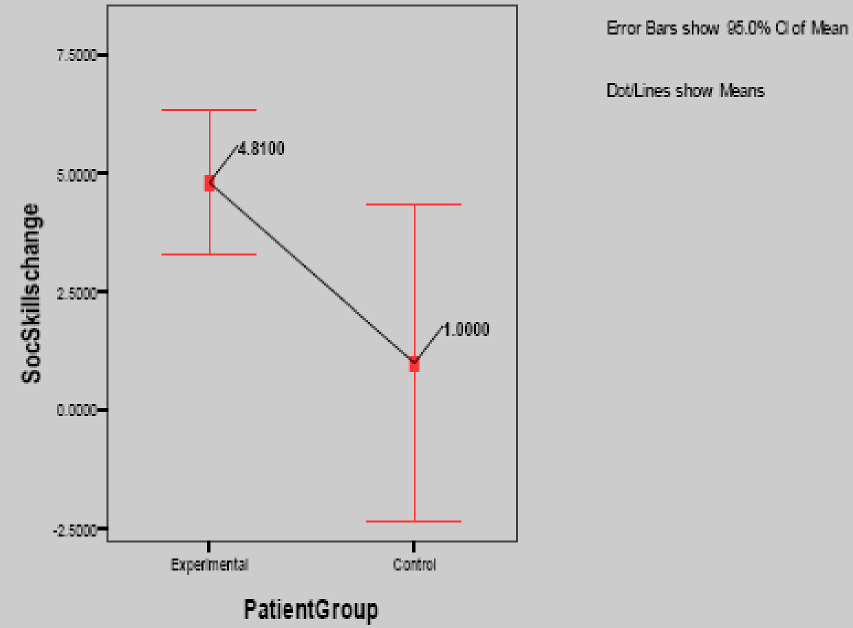


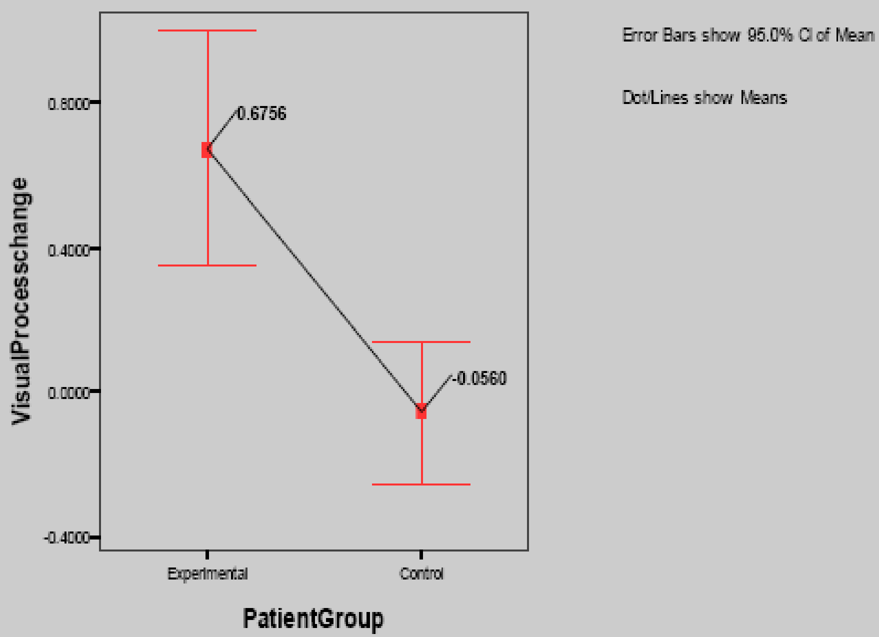
Neurofeedback for social skills deficits in Autism Spectrum Disorders

Robert Coben, Ph.D.[1], Aishwarya Balasubramaniyan, M.S.[2], Nicholas Lofthouse, Ph.D.[2], N. Kyle Jamison, B.S.[2], Elizabeth Hurt, Ph.D.[2], & L. Eugene Arnold, M.D., M.Ed.[2]
[1]Integrated Neuroscience Services
[2]The Ohio State University Wexner Medical Center

Abstract
Due to the limitations of existing treatments for autism spectrum disorders (ASD) and strong evidence for neurological deficits in ASD, the complementary/alternative and neural connectivity-based intervention of neurofeedback (NF) was examined. QEEG coherence-based training targeting social skills deficits was administered to 25 children with ASD and compared to 25 randomized matched waitlist controls. Relative to the latter, the NF group had significant pre-post treatment improvements, with medium-large effect sizes in social skills, visual processing and overall behaviors. Significant EEG NF-related improvements were also shown in the neural substrates related to visual/facial/emotional processing.







ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	172.365	1	172.365	4.372	.042[a]
	Residual	1892.340	48	39.424		
	Total	2064.705	49			

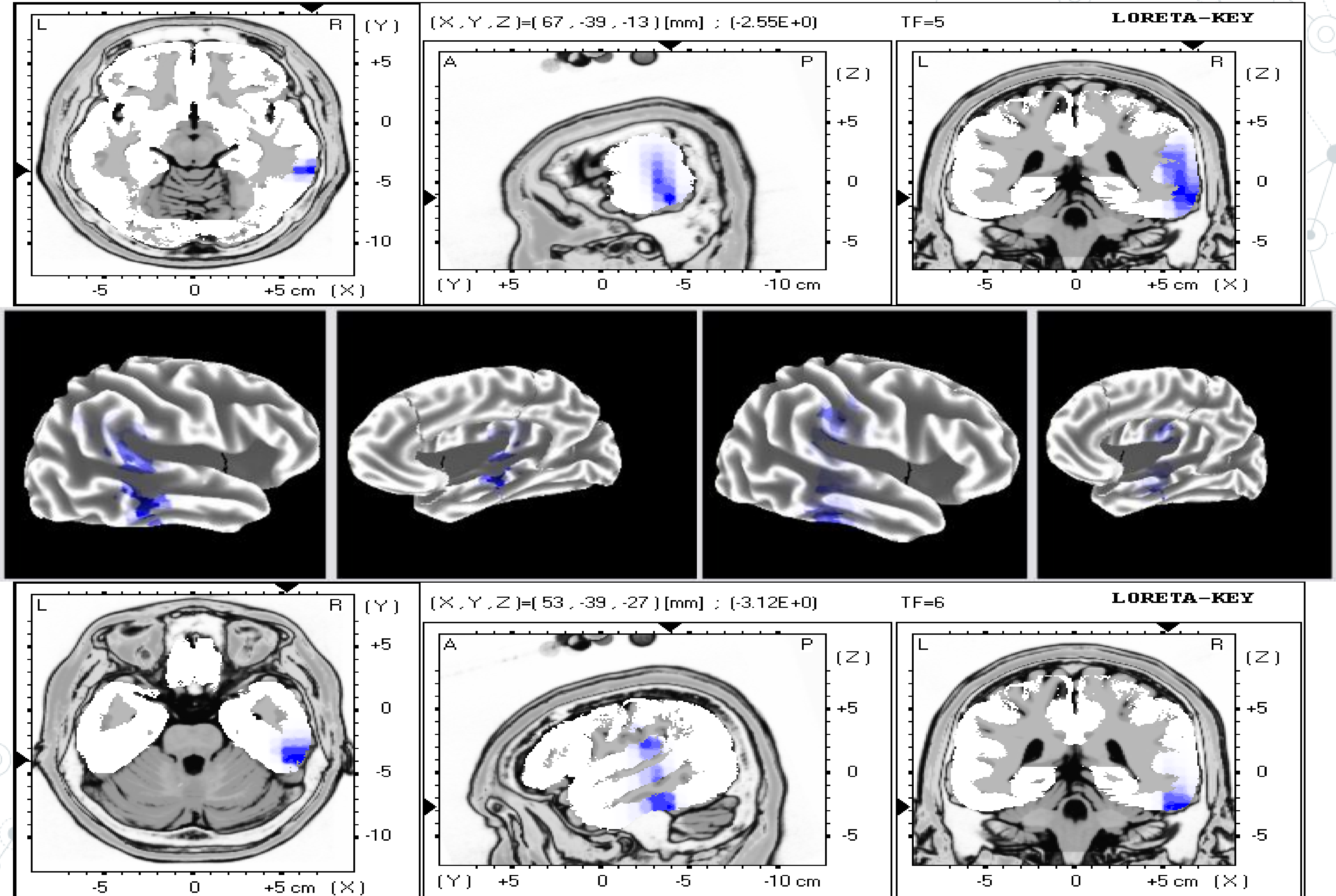
a. Predictors: (Constant), VisualProcesschange

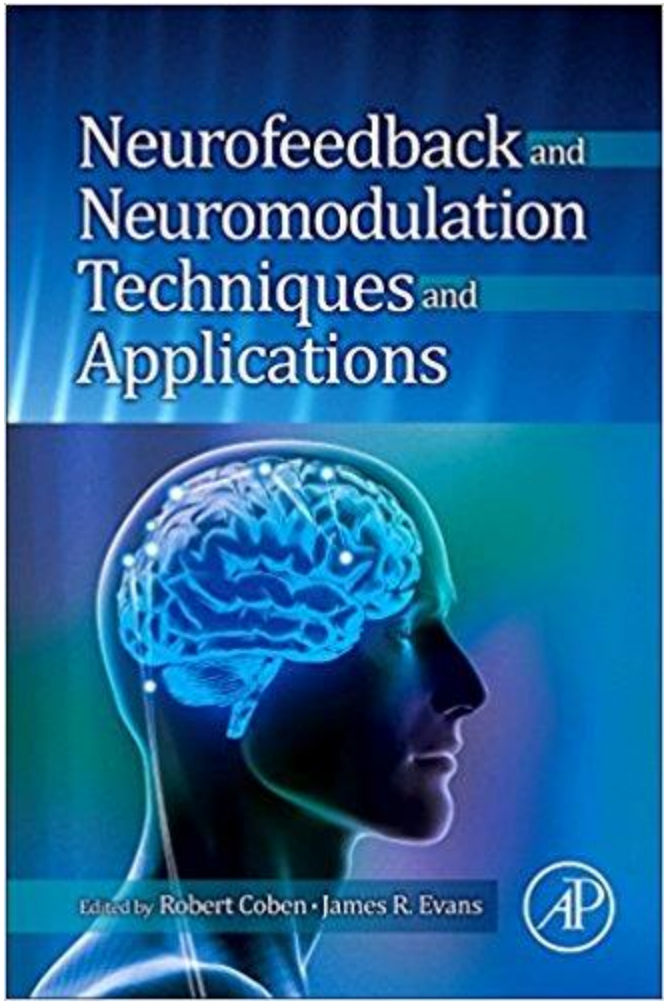
b. Dependent Variable: SocSkillschange

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.289[a]	.083	.064	6.2788328

a. Predictors: (Constant), VisualProcesschange


(X,Y,Z)=(67 , -39 , -13) [mm] ; (-2.55E+0)
TF=5
LORETA-KEY
L
R
(Y)
+5
0
-5
-10
-5
0
+5 cm
(X)
A
P
(Z)
(Y)
+5
0
-5
-10 cm
(X,Y,Z)=(53 , -39 , -27) [mm] ; (-3.12E+0)
TF=6
LORETA-KEY



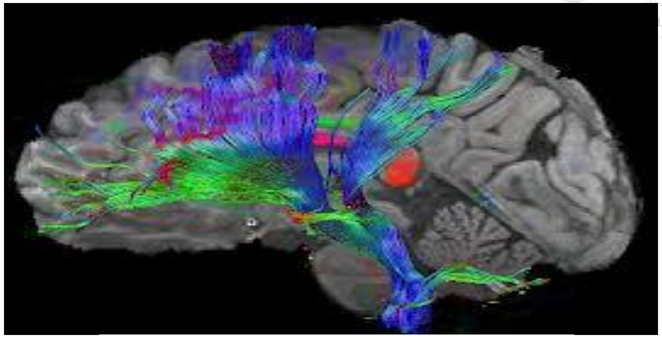
Emerging Empirical Evidence Supporting Connectivity-Guided Neurofeedback for Autistic Disorders

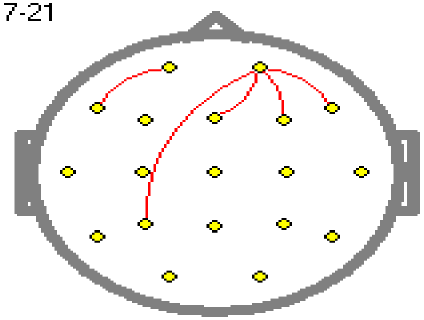
Robert Coben and Lori A. Wagner
Neurorehabilitation and Neuropsychological Services, Massapequa Park, New York, USA

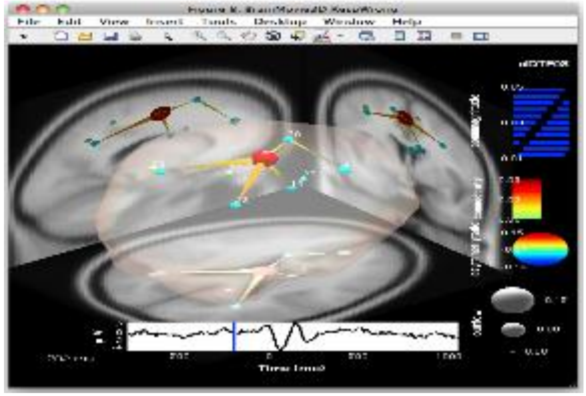
Neurofeedback and Neuromodulation Techniques and Applications
DOI: 10.1016/B978-0-12-382235-2.00006-8

Types of connectivity

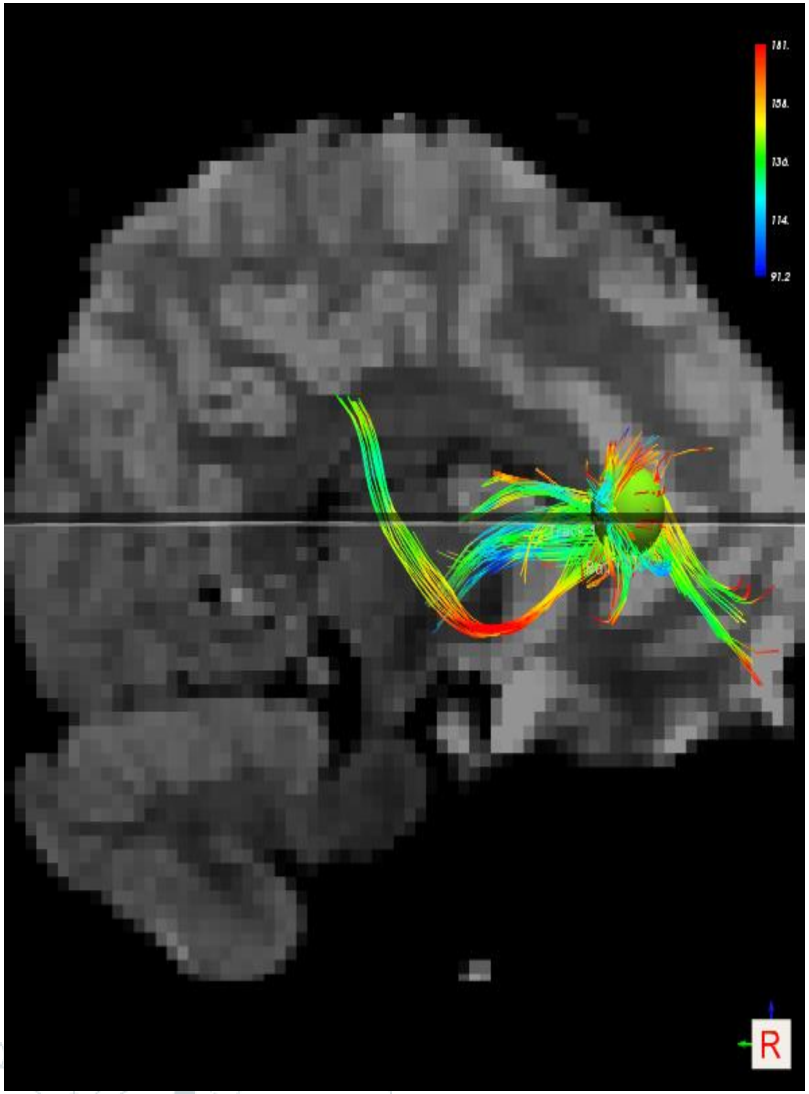
- Structural connectivity
- Functional connectivity
- Effective connectivity

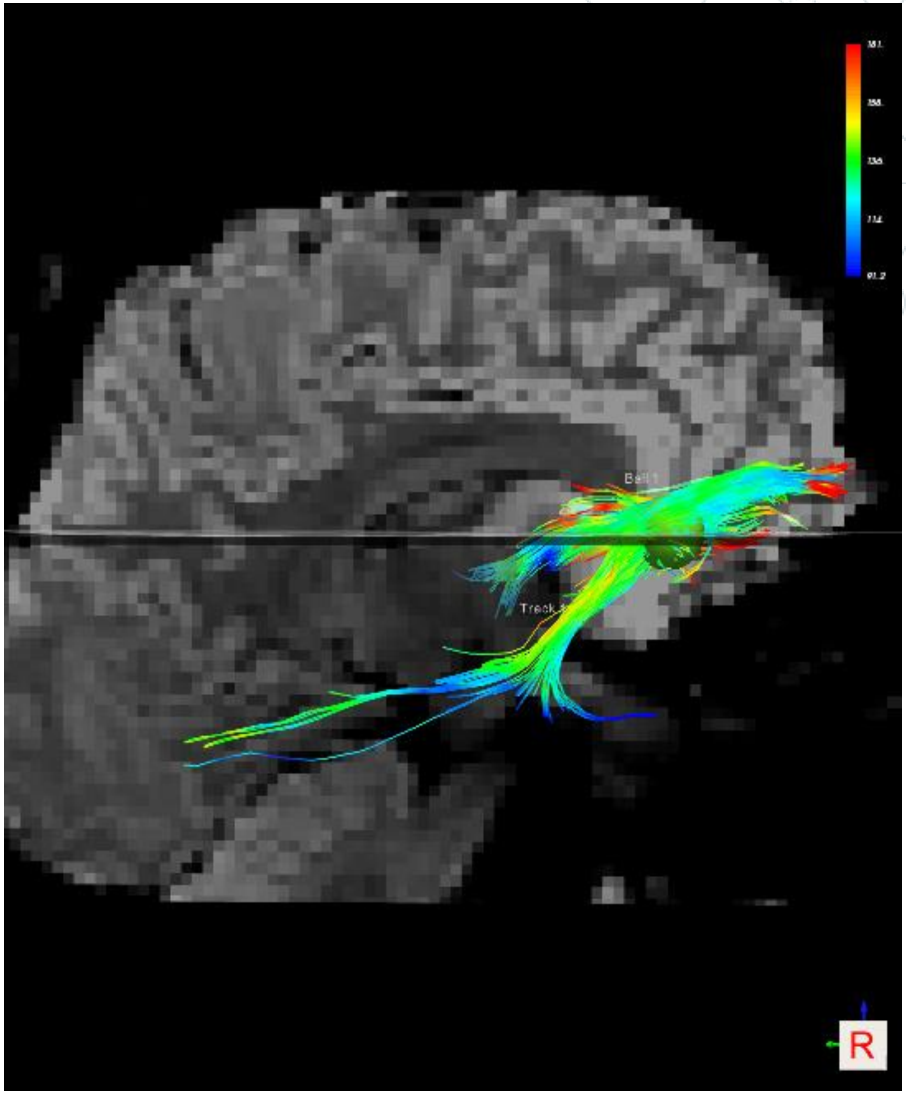


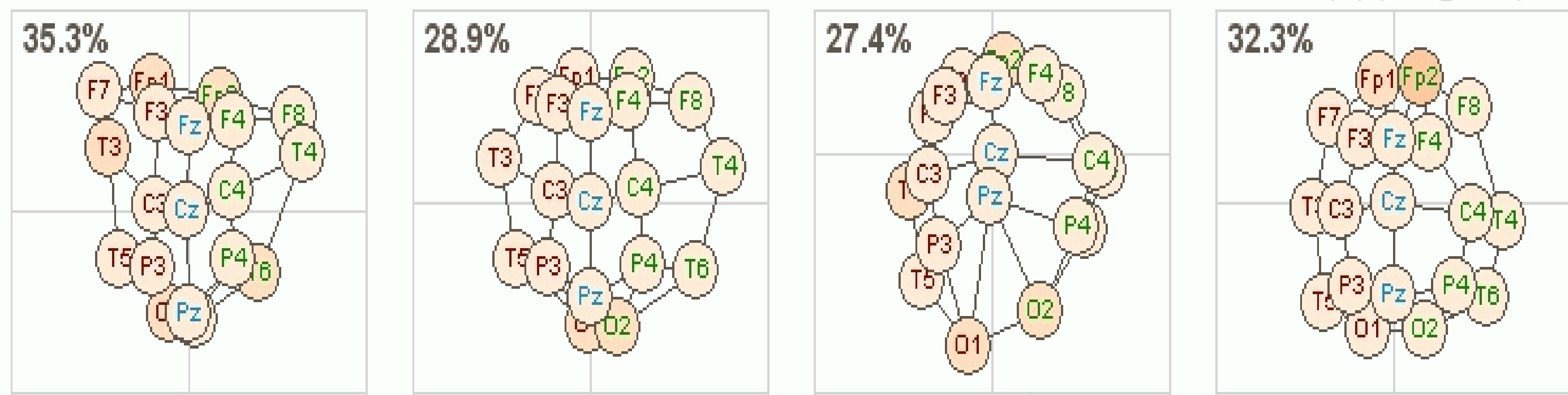




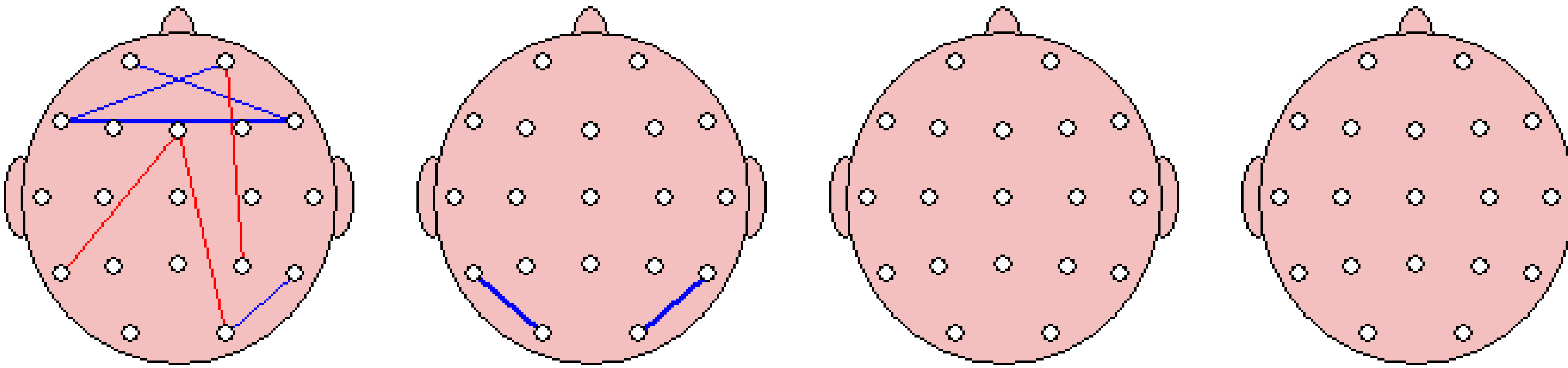
Comparing DTI to Coherence measurements







Delta (1.0 - 4.0 Hz) | Theta (4.0 - 8.0 Hz) | Alpha (8.0 - 12.0 Hz) | Beta (12.0 - 25.0 Hz)



Med Biol Eng Comput (2011) 49:521–529
DOI 10.1007/s11517-011-0739-x

SPECIAL ISSUE - REVIEW

Review of the methods of determination of directed connectivity from multichannel data

Katarzyna J. Blinowska

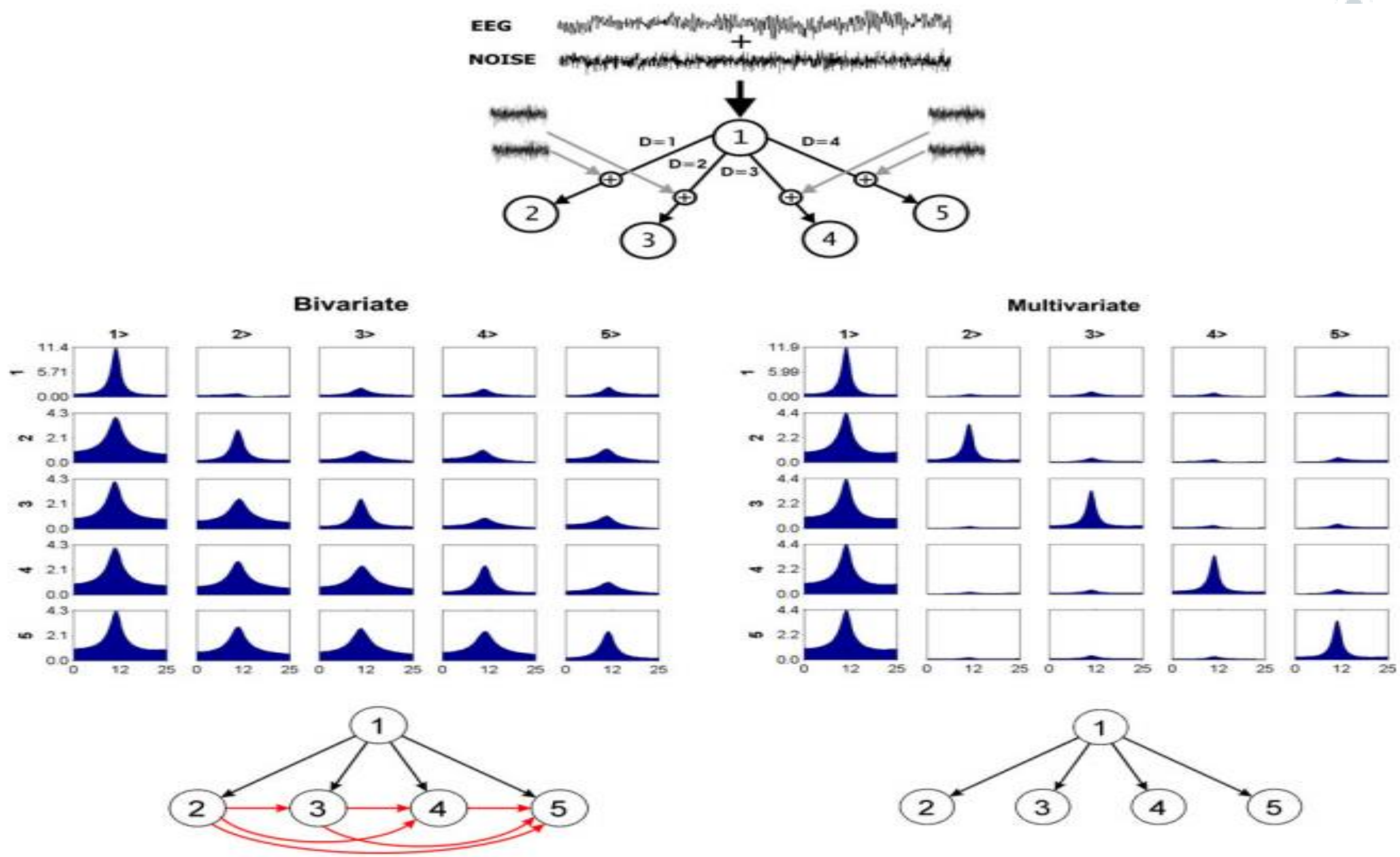
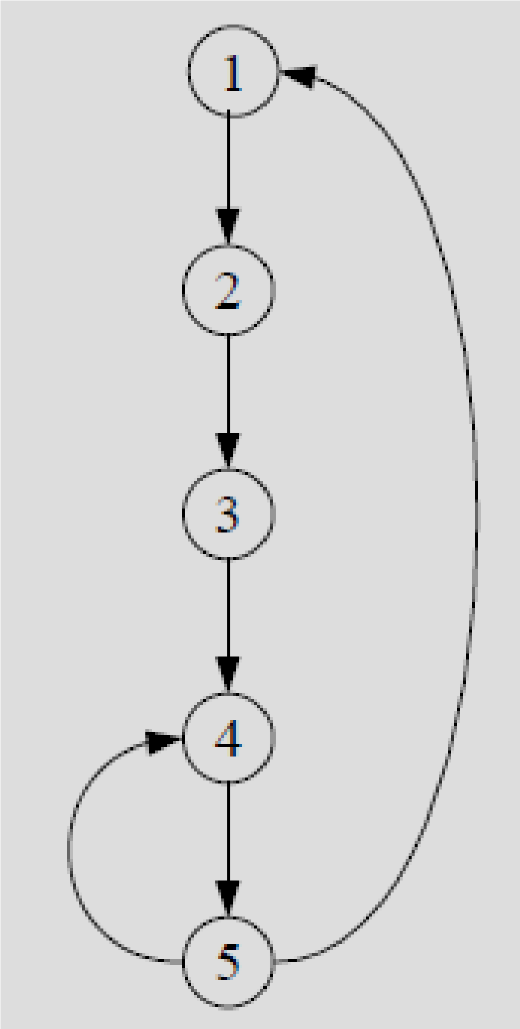
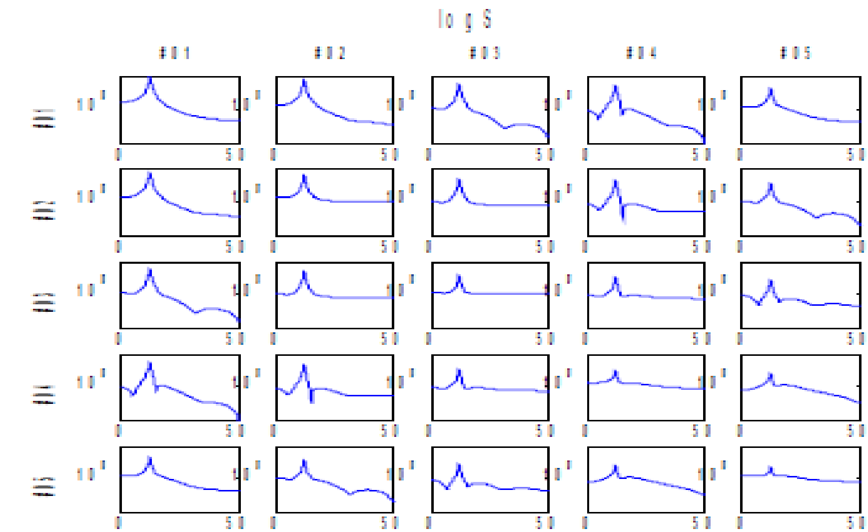


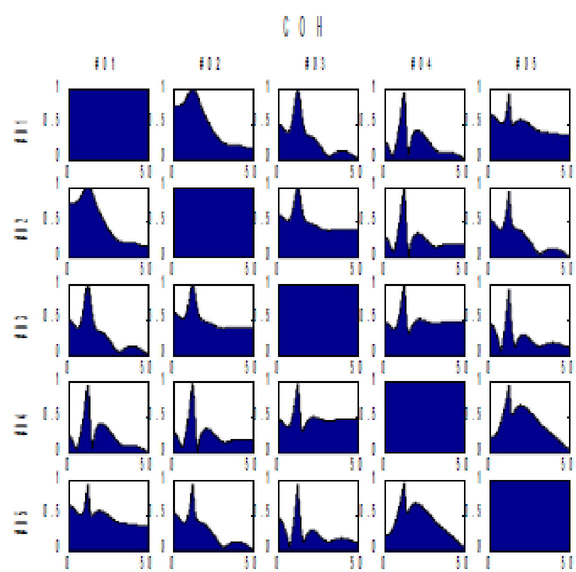
Fig. 1 Comparison of bivariate and multivariate methods of estimation of directed connectivity. *Top* simulation scheme (*D* delay value, at each step white noise is added). *Bottom* connectivity measures, at the *left* bivariate, at the *right* multivariate. Propagation from the channel marked above the column to the channel marked at *left*. In each *box* DTF is shown as a function of frequency. At the diagonal power spectra. At the very *bottom* obtained connections schemes

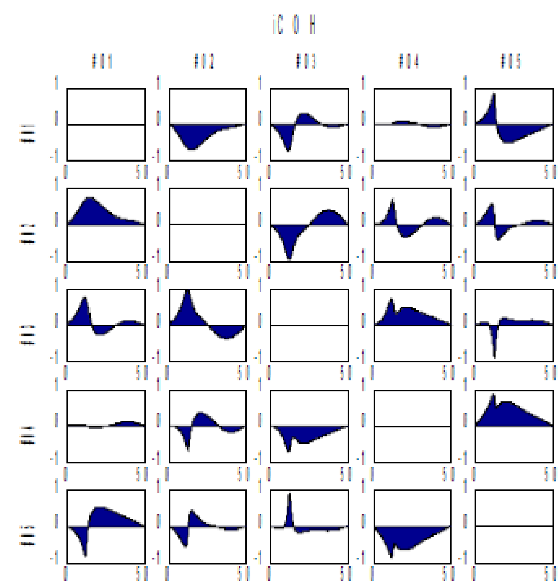


Auto- & Crossspectra

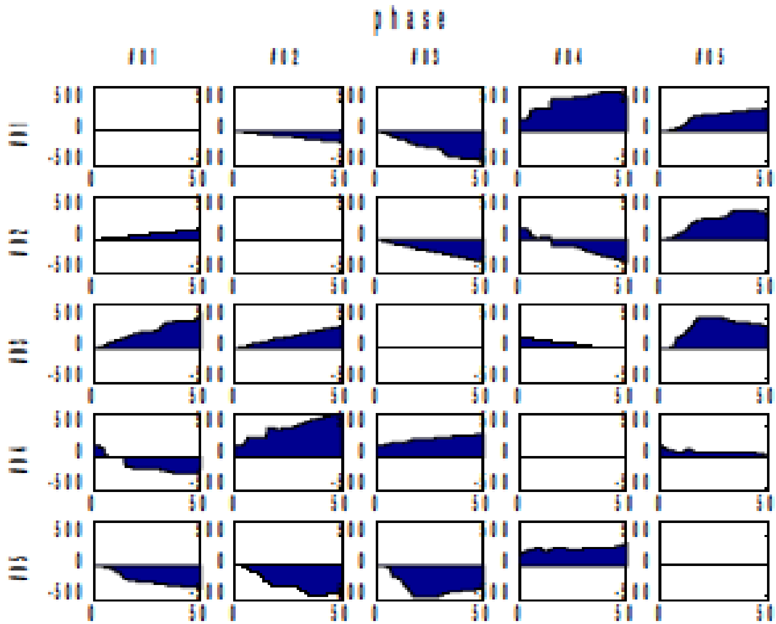


Coherency, Coherence (COH)

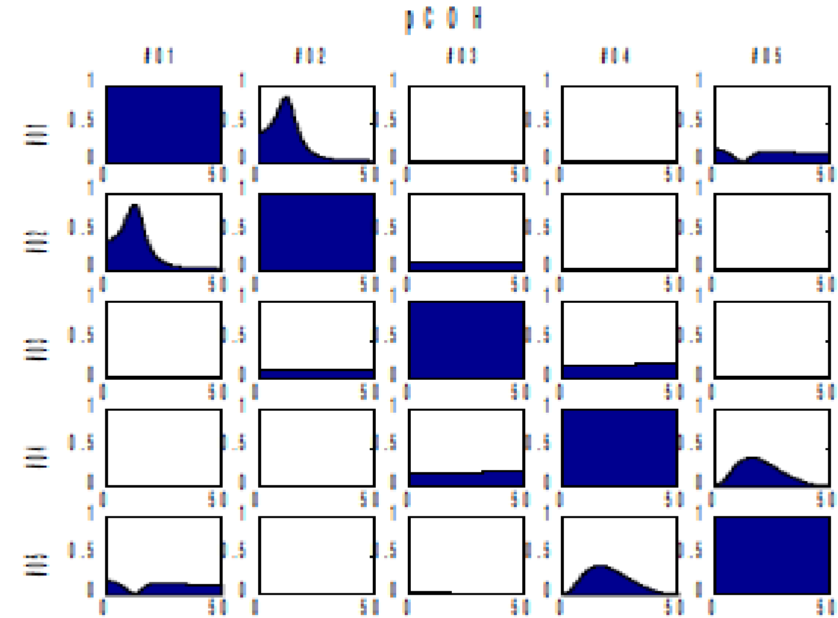




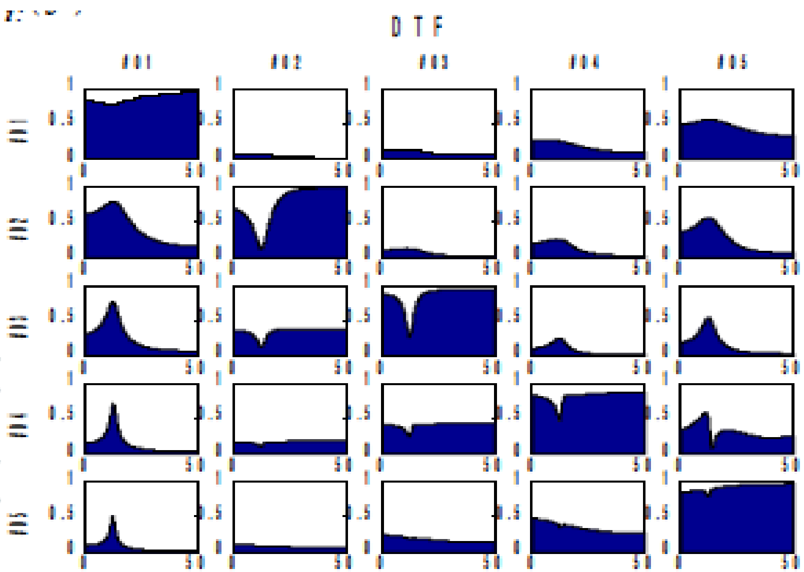
Phase differences and time delay



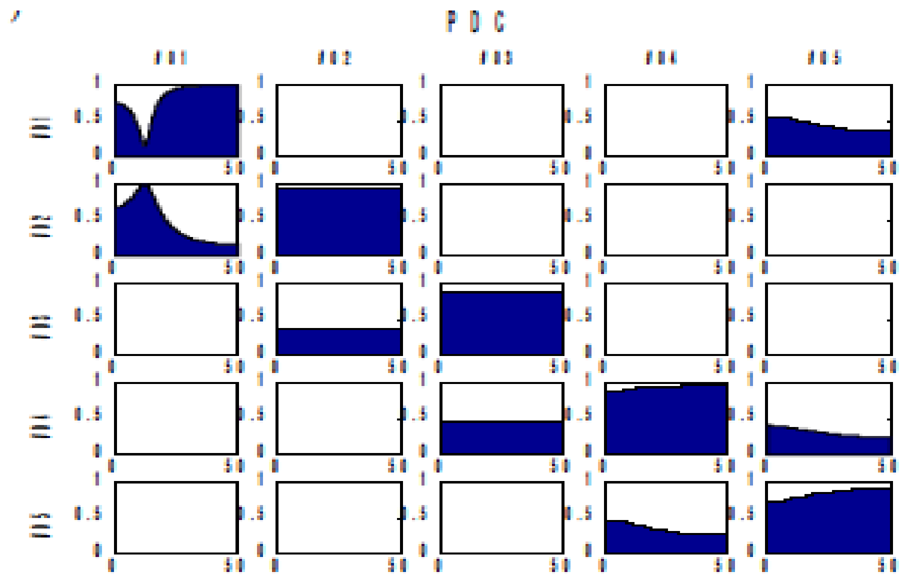
partial Coherence (pCOH)



Directed Transfer Function (DTF)



Partial Directed Coherence (PDC)



Using quantitative and analytic EEG methods in the understanding of connectivity in autism spectrum disorders: a theory of mixed over- and under-connectivity

Robert Coben[1,2]*, Iman Mohammad-Rezazadeh[3,4] and Rex L. Cannon[5]

[1] Neurorehabilitation and Neuropsychological Services, Massapequa Park, NY, USA
[2] Integrated Neuroscience Services, Fayetteville, AR, USA
[3] Center for Mind and Brain, University of California, Davis, CA, USA
[4] Semel Institute for Neuroscience and Human Behavior, University of California, Los Angeles, CA, USA
[5] Psychoeducational Network, Knoxville, TN, USA

Frontiers in Human Neuroscience www.frontiersin.org February 2014 | Volume 8 | Article 45 | 1

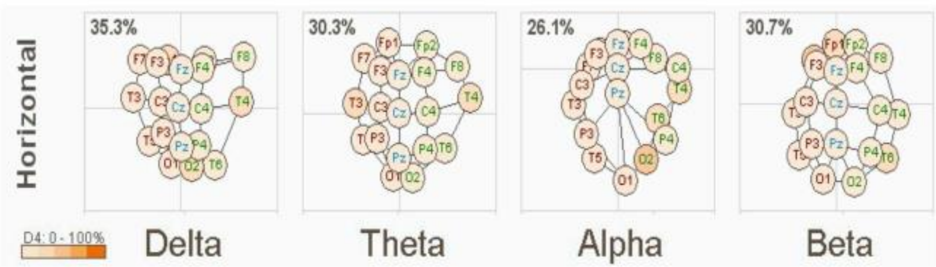


FIGURE 1 | NeuroRep Multivariate Connectivity analyses showing eigen images in the horizontal place across delta, theta, alpha, and beta frequencies. Observable features include; (1) right hemisphere (temporal) hypocoherences across all frequency bands, (2) hypercoherences in the alpha band over prefrontal regions, and (3) right parietal-posterior temporal hypercohences in the theta and alpha frequency bands.

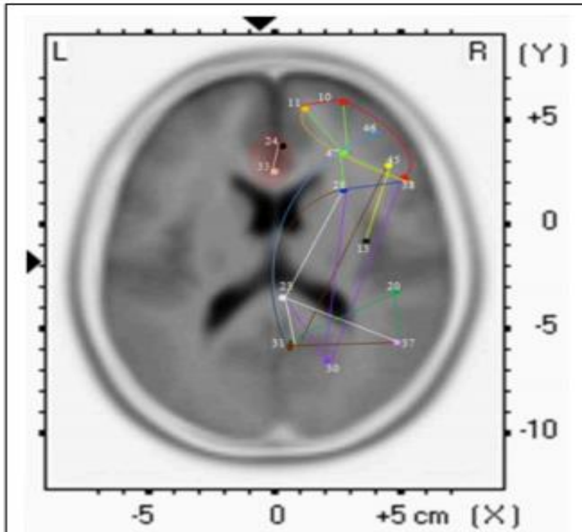


FIGURE 3 | Each of the 15 ROIs for this case study are represented in a different color. The lines indicate significant correlations between the colored ROI and other regions. The color of the line is the same as the ROI in relation to its functional connectivity with other ROIs.

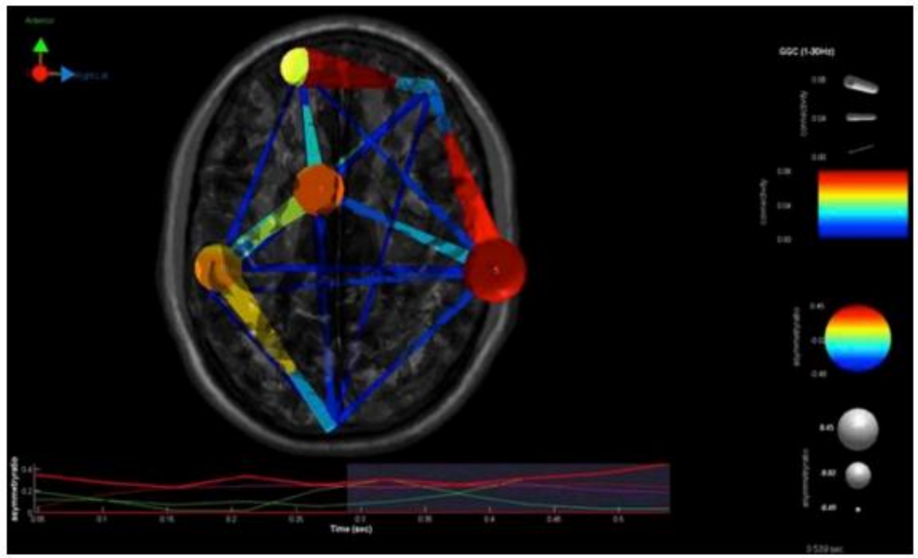
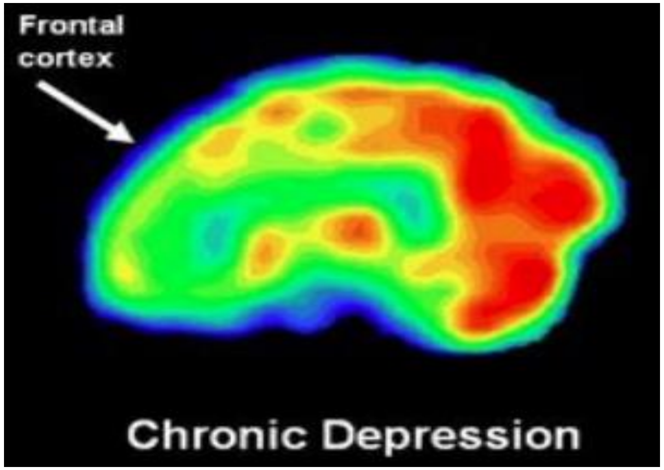
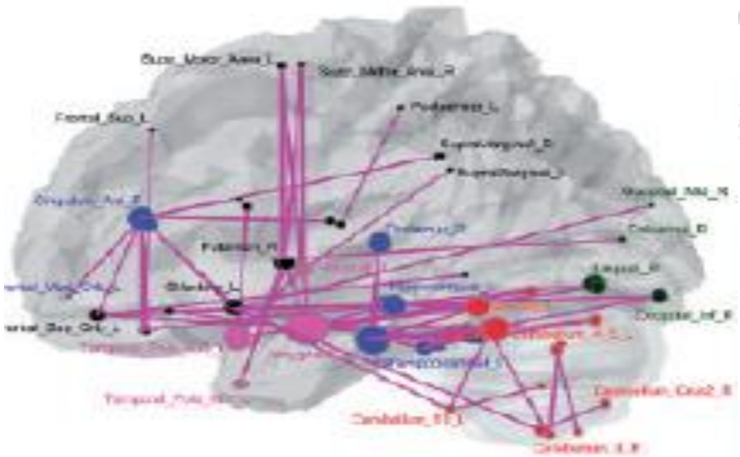
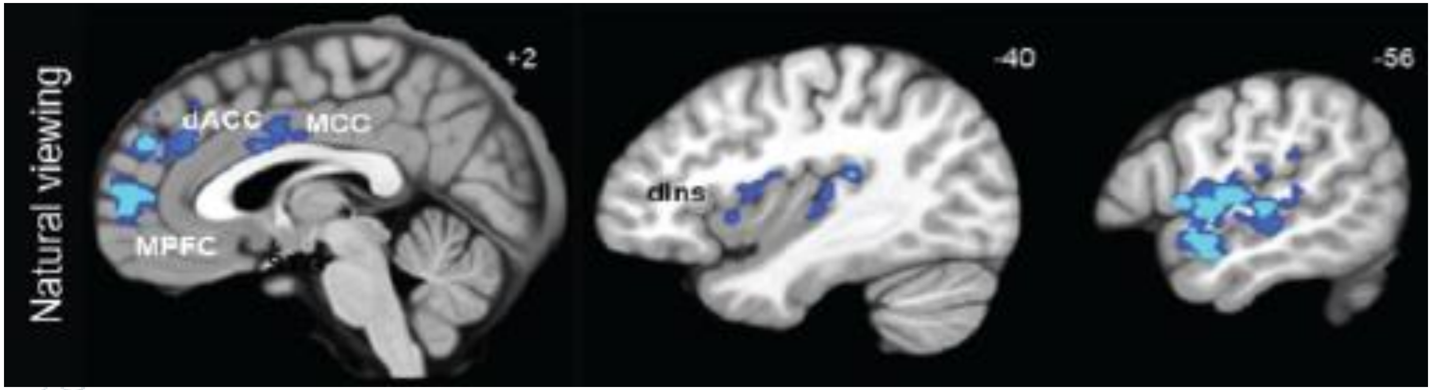


FIGURE 5 | SIFT/Granger (GGC) causality brain image. Levels of greater connectivity are shown with thicker lines and brighter colors. Direction of causality is indicated by the key in the upper left hand corner. ICs and their localization are listed as part of **Table 3**.

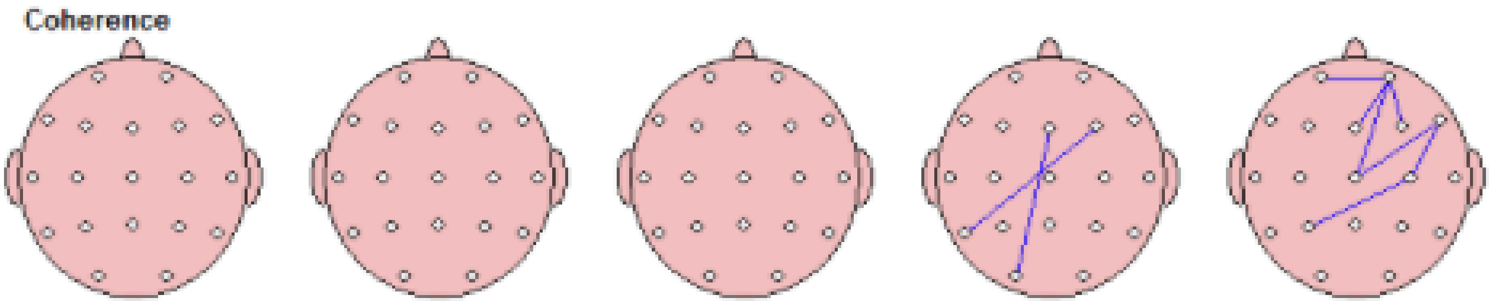
Exemplar: Major Depression

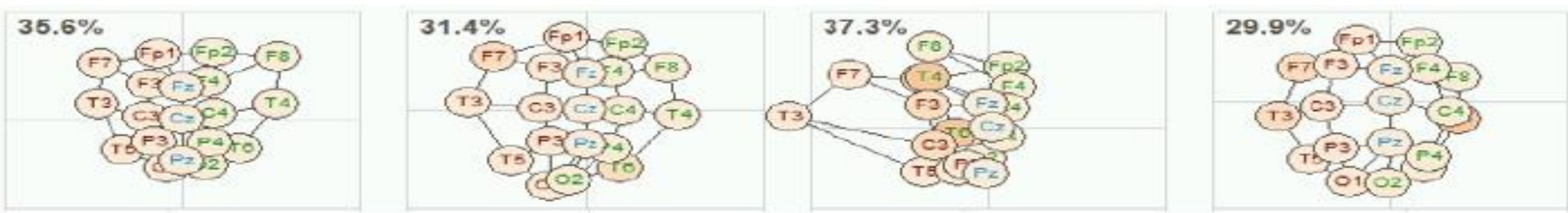


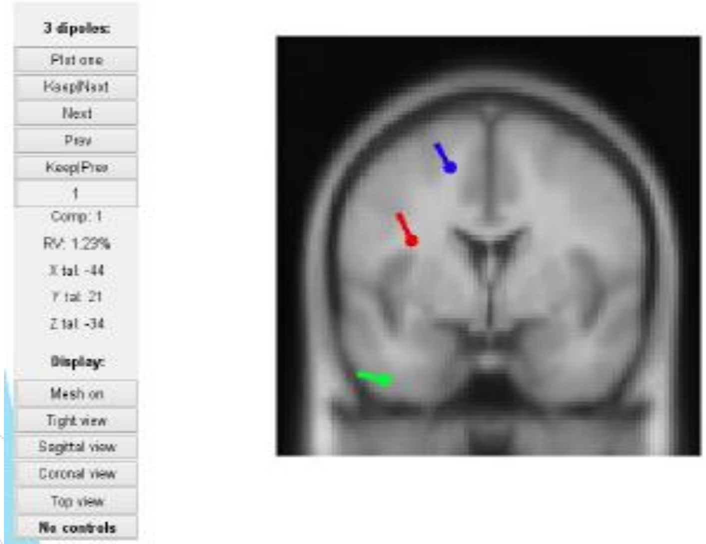


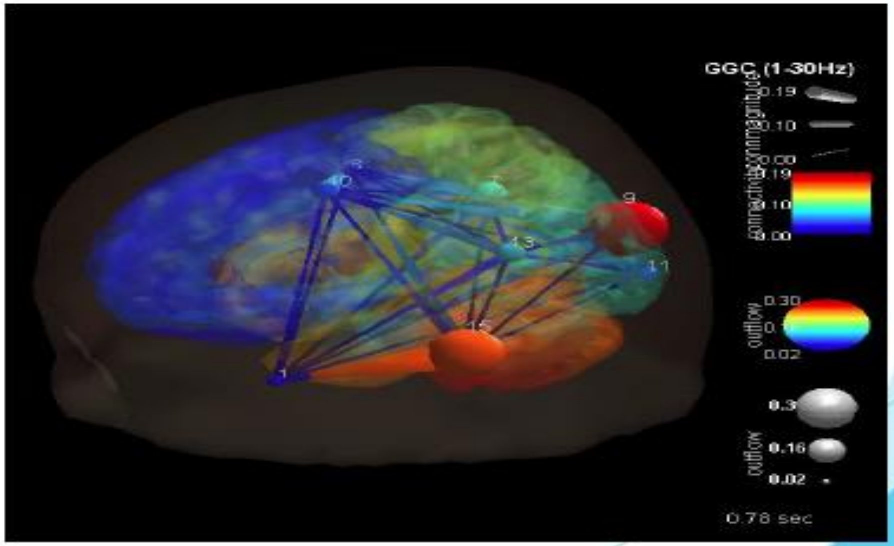


Exemplar: Major Depression



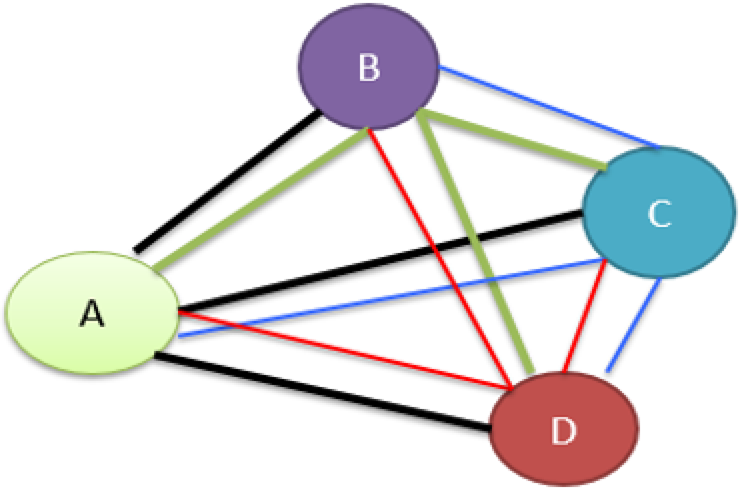






QPS: Averaging coherences

- A method of combining averaged psync values.
  - 4 channels of EEG
  - Each pair has a running psync calculation
  - For each channel, the 3 pairs of psync values are computed, averaged and this is used as the output reward value
  - If a raw channel is in artifact condition, the channel is not used in the averaging calculation



A = (AB + AC + AD)/3
B = (BA + BC + BD)/3
C = (CA + CB + CD)/3
D = (DA + DB + DC)/3

QPS Ave = (A + B + C + D)/4

QPS Average

- 3 modes:
  - Avg: average value (sum/samples)/number of samples
  - Dev: difference in the range of values
  - Mod: simultaneous combination of avg and dev

n=number of values NOT in artifact
v=Psync value
Avg=average value result

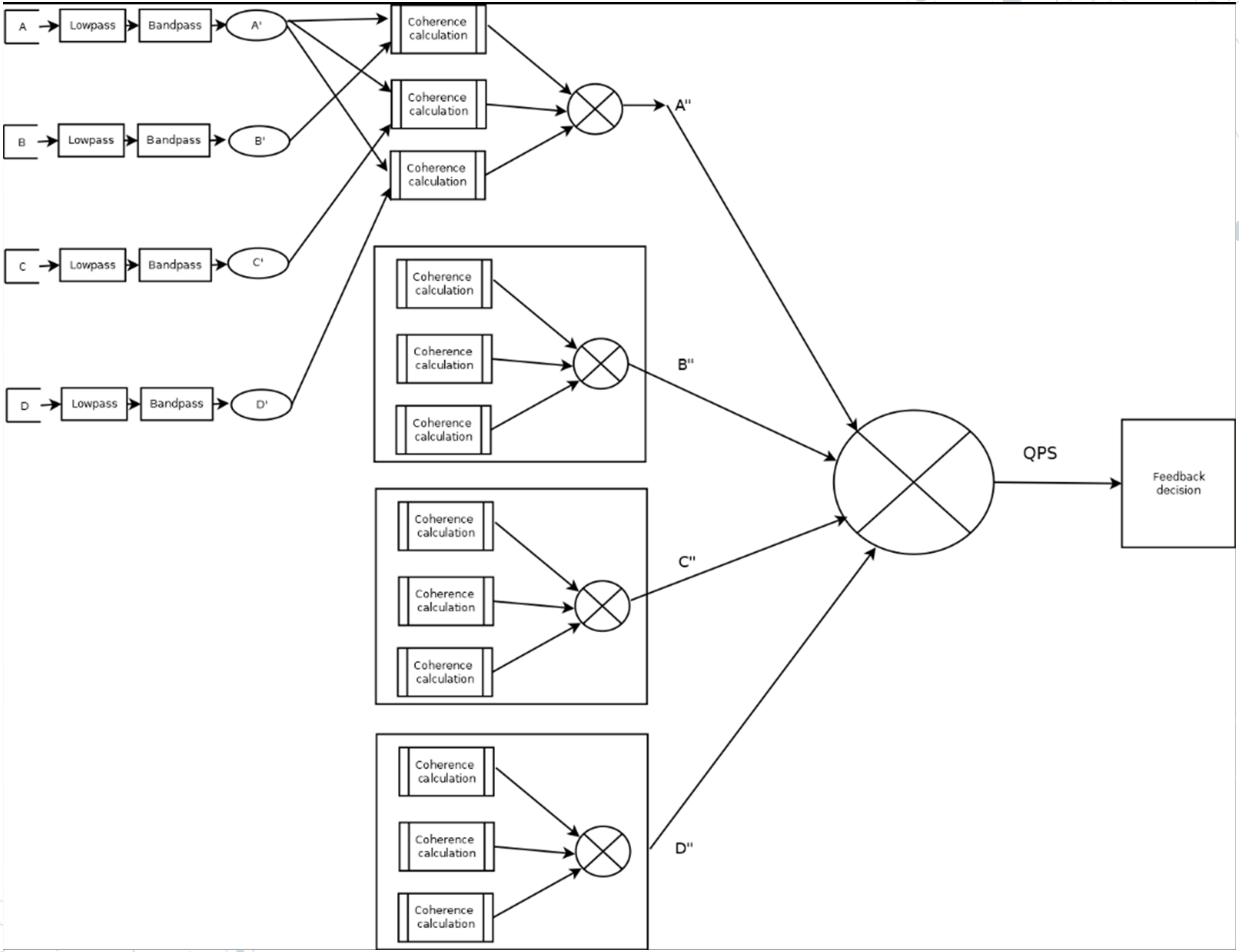
$$Avg=\left(\sum_1^n (v_i)\right)/n$$

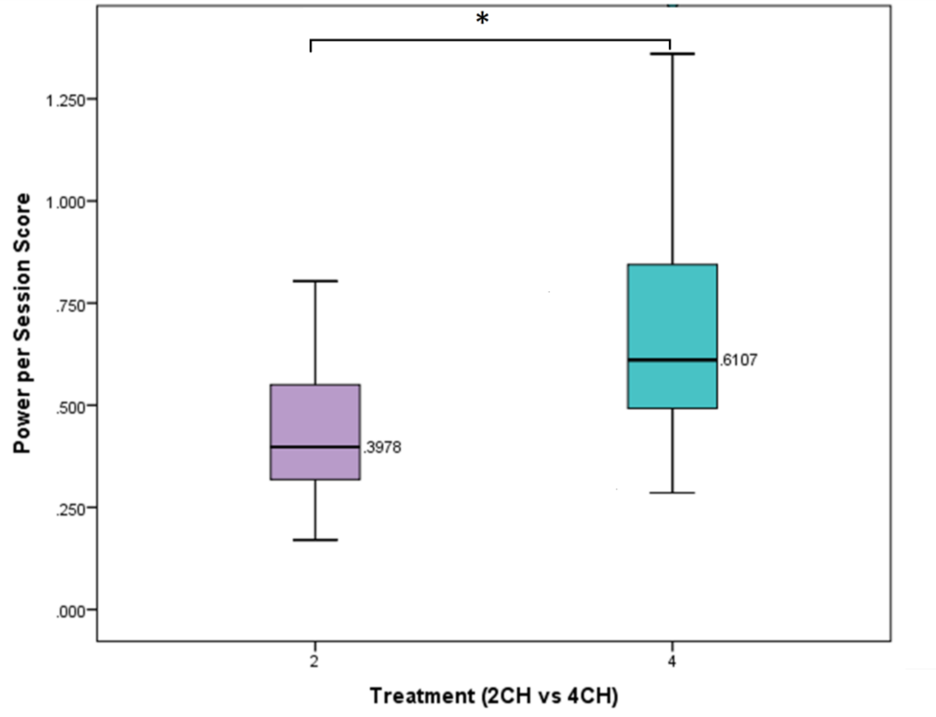
compute Avg like submode AVG

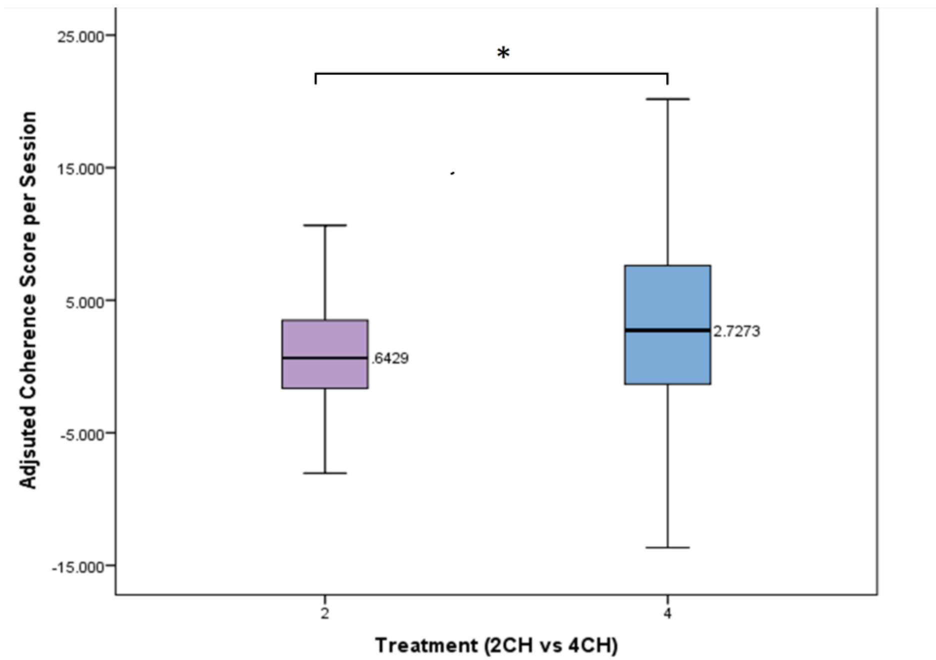
$$answer=\sqrt{\left(\sum_1^n (v_i - Avg)^2\right)}$$

Anecdotal evidence

- Obsessive-Compulsive Disorder
- Seizures
- Autism
- TBI
- Dyslexia
- Speech/Language
- Emotional regulation
- Depression
- Developmental trauma/PTSD

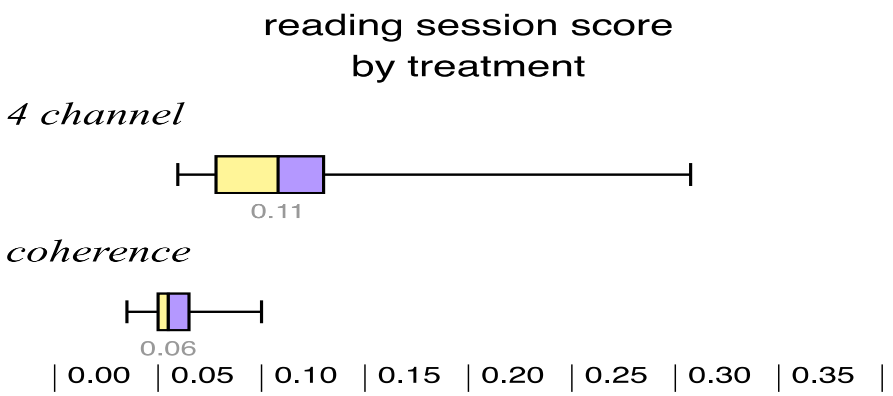

A
Lowpass
Bandpass
A'
B
Lowpass
Bandpass
B'
C
Lowpass
Bandpass
C'
D
Lowpass
Bandpass
D'
Coherence calculation
Coherence calculation
Coherence calculation
A''
Coherence calculation
Coherence calculation
Coherence calculation
B''
Coherence calculation
Coherence calculation
Coherence calculation
C''
Coherence calculation
Coherence calculation
Coherence calculation
D''
QPS
Feedback decision


*
1.250
1.000
.750
.500
.250
.000
Power per Session Score
.3978
.6107
2
4
Treatment (2CH vs 4CH)


*
25.000
15.000
5.000
-5.000
-15.000
Adjsuted Coherence Score per Session
.6429
2.7273
2
4
Treatment (2CH vs 4CH)

Controlled Analysis of EEG Coherence and it's impact on Learning Disabilities

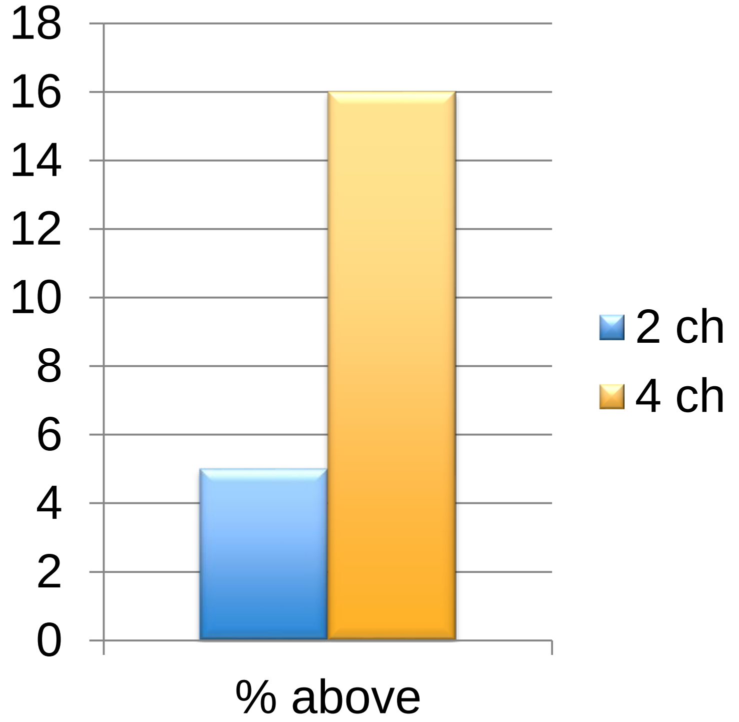
Robert Coben, PhD
Co-Founder/Neuropsychologist, integrated neuroscience services, LLC
Presented at ISNR 2015, Denver, Colorado



Group Statistics

	treatment	N	Mean	Std. Deviation	Std. Error Mean
reading change age	two channel	21	1.243	.4044	.0883
	4 channel	21	1.628	.8313	.1814

Number above 1 month per session

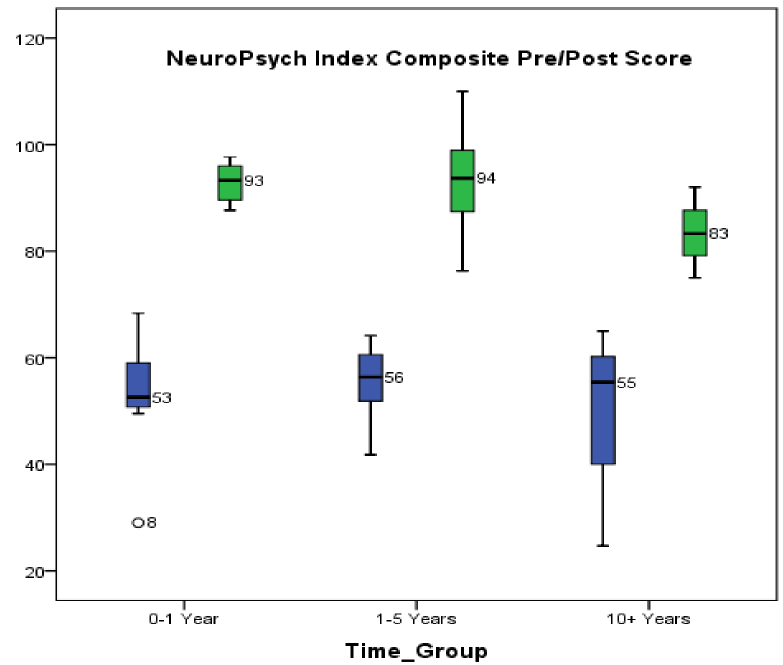


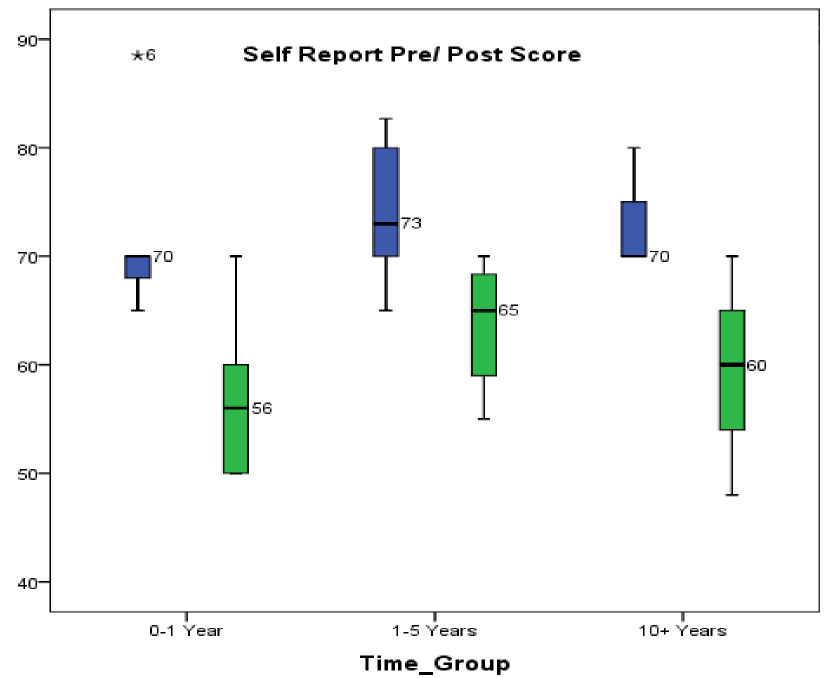
The Use of Four Channel Multivariate coherence Training on Mild Traumatic Brain Injury:

A comparison of newly concussed and remotely concussed individuals

Presented at the 25th Annual ISNR Conference, September, 2017, Foxwoods, CT

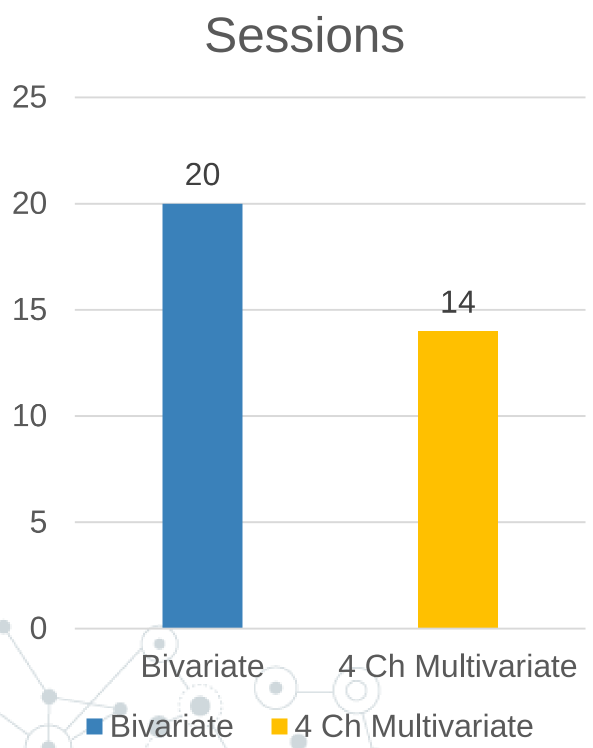
Anne Stevens, Ph.D., Morgan Middlebrooks, BA
Integrated Neuroscience Services, Fayetteville, Arkansas

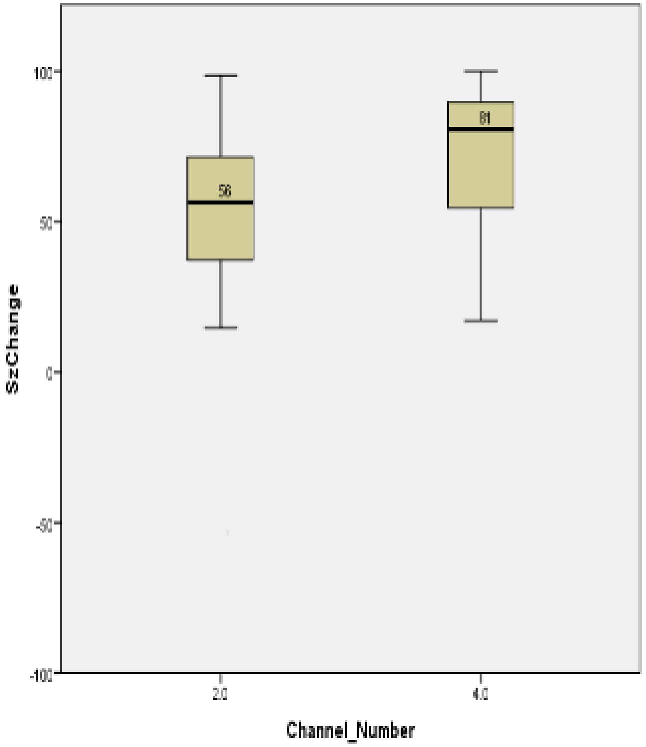


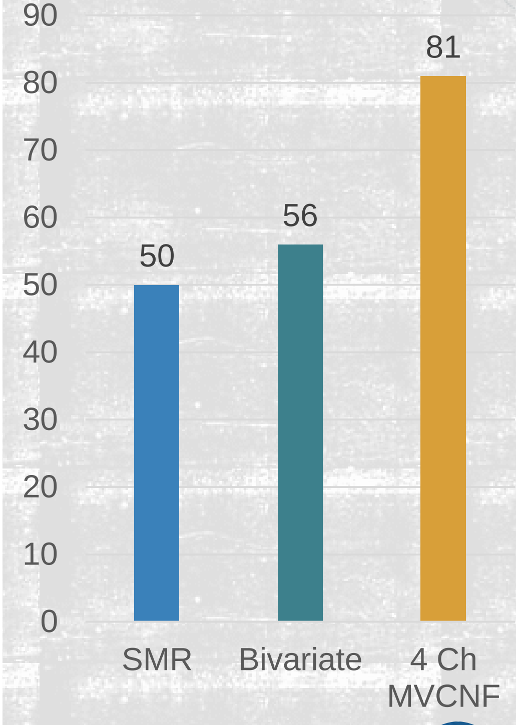


Relative efficacy of two different forms of Coherence Neurofeedback for Seizure Disorders

Morgan Middlebrooks, BA, Robert Coben, PhD, Janease Traylor, MS

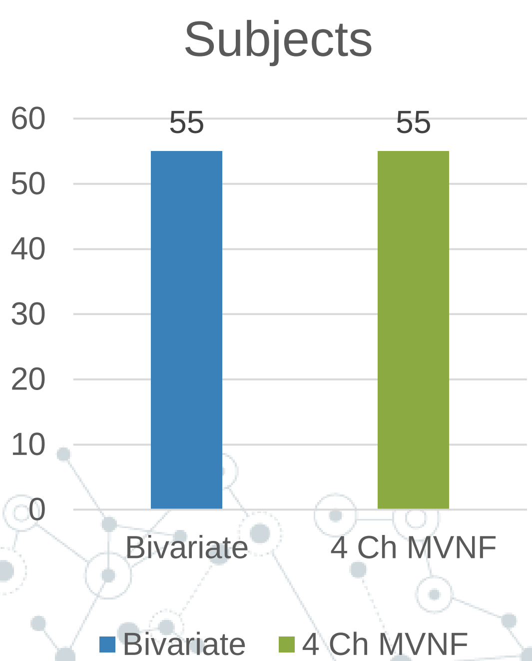


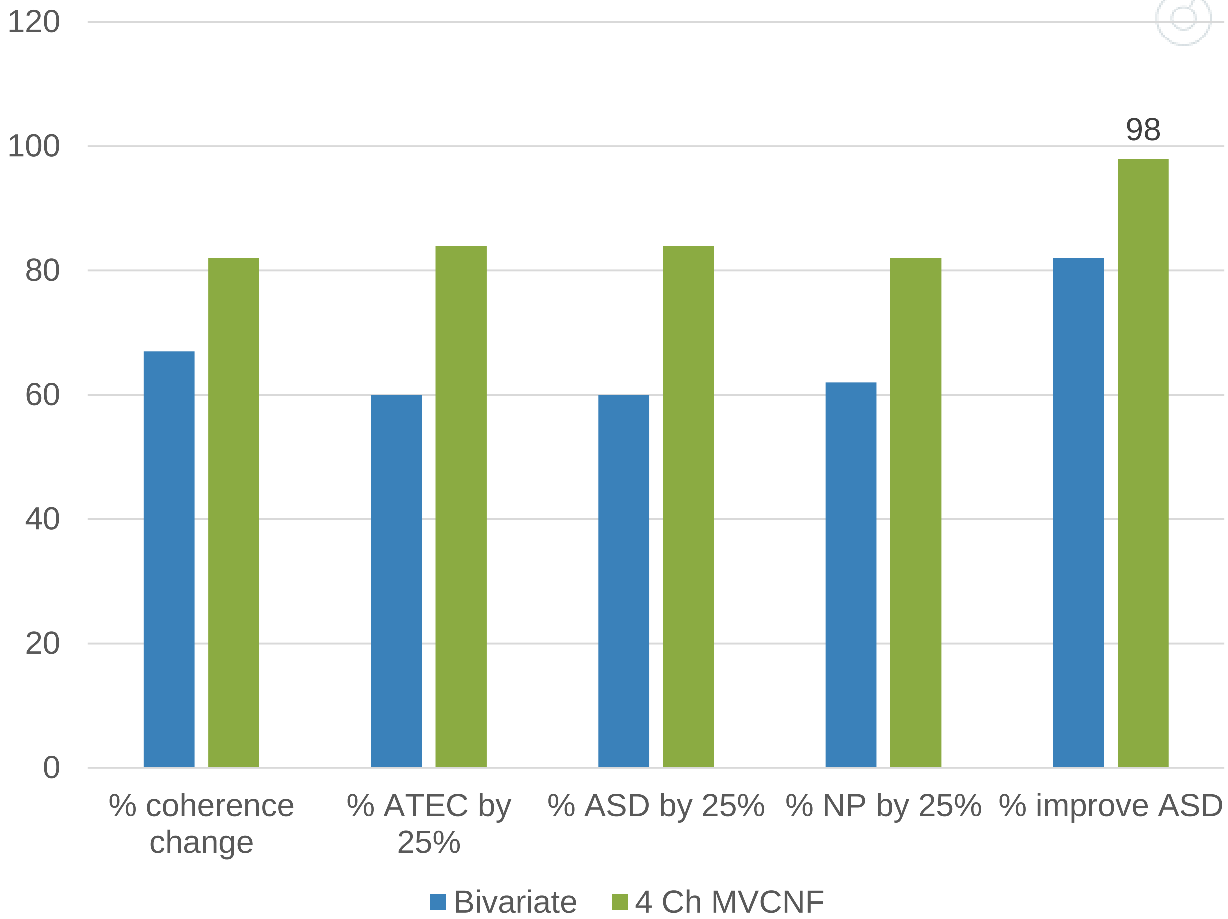




Comparing Bivariate and Multivariate Coherence Neurofeedback for Autism Spectrum Disorder

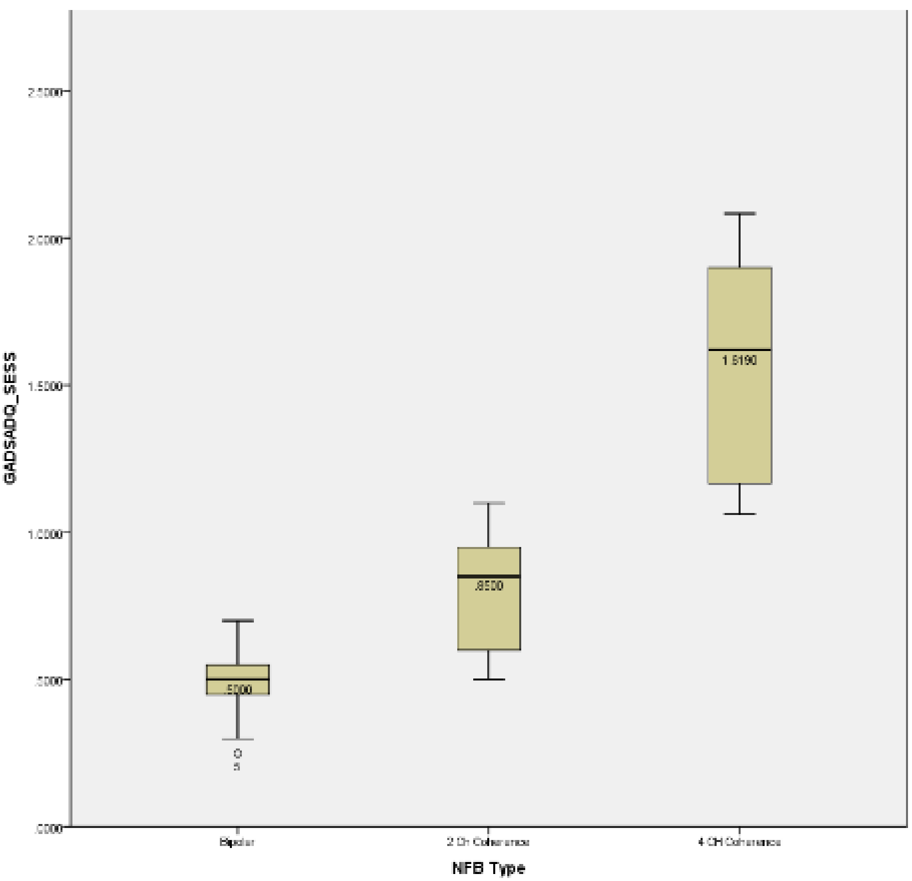
Robert Coben, PhD and Morgan Middlebrooks, BA

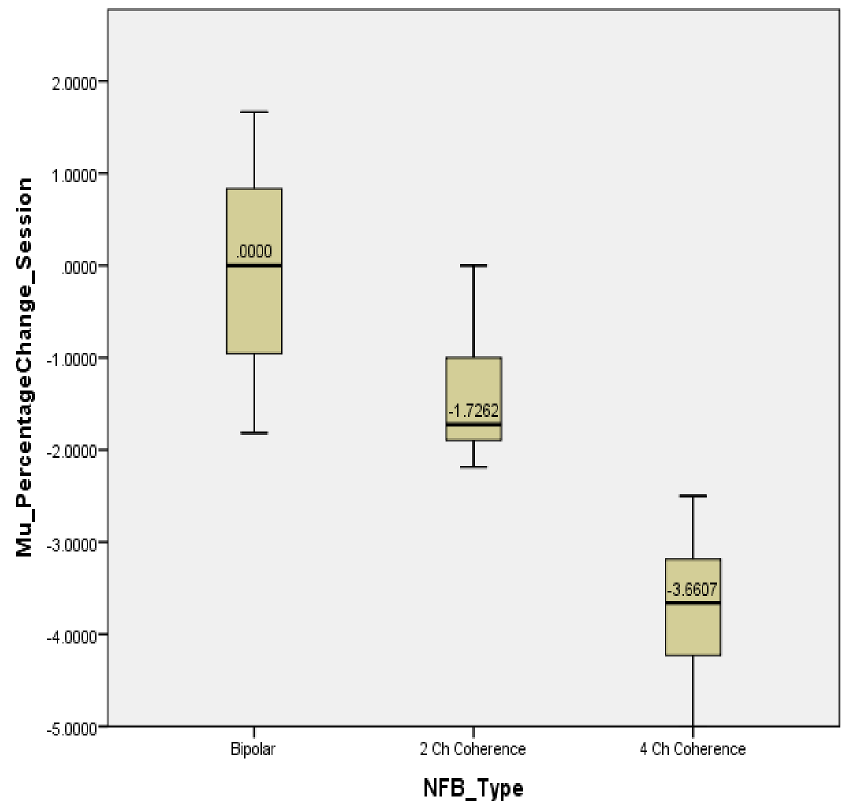


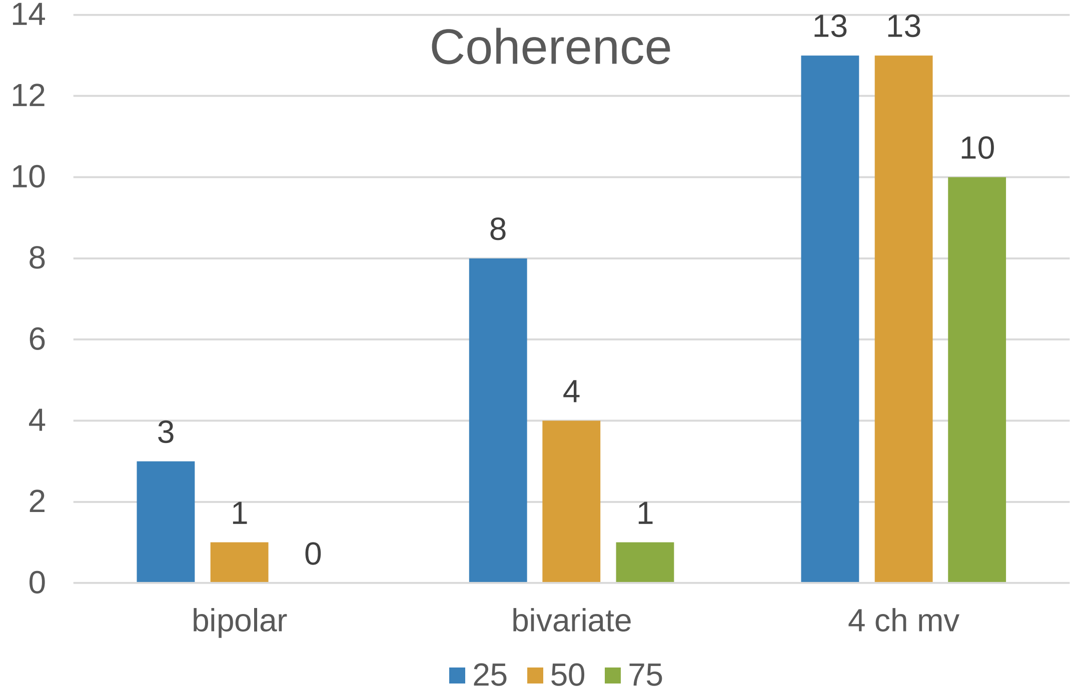


Exploring the impact of single channel, bivariate and multichannel coherence training on Mu suppression deficits in Autism Spectrum Disorders

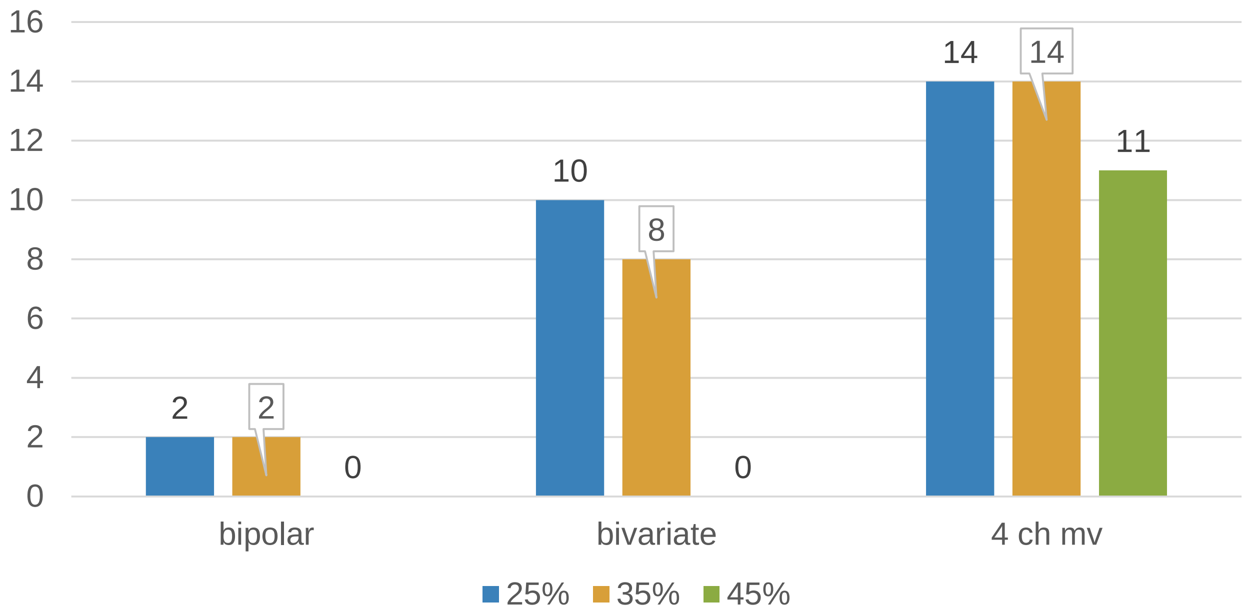
Janease Traylor, MS and Robert Coben, PhD







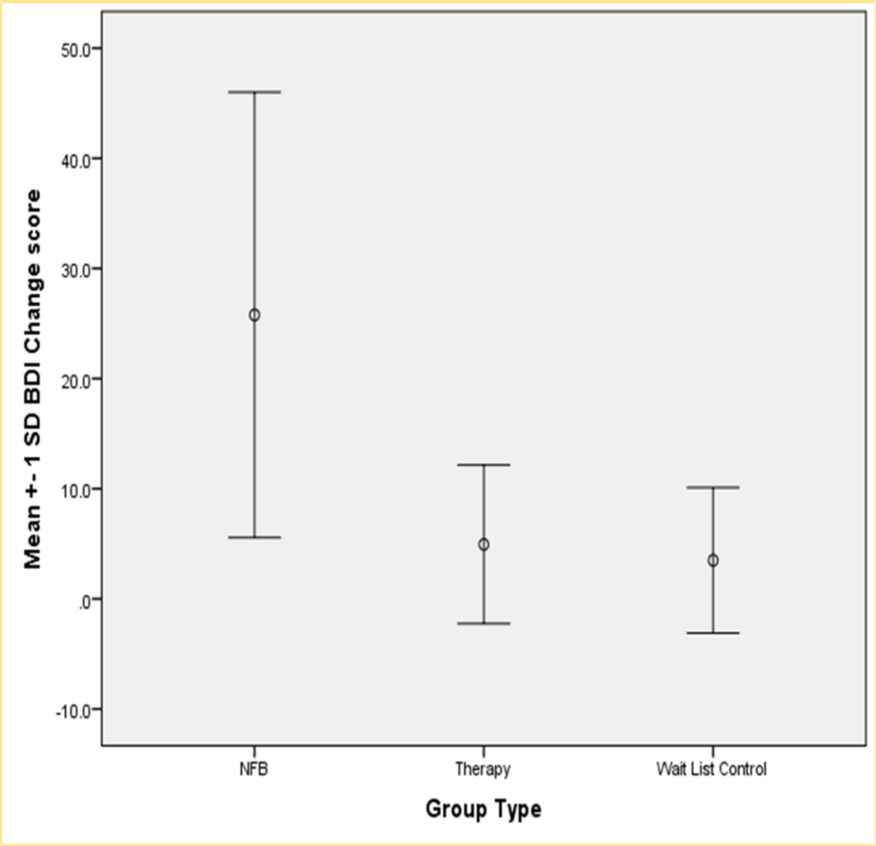
Mu Suppression

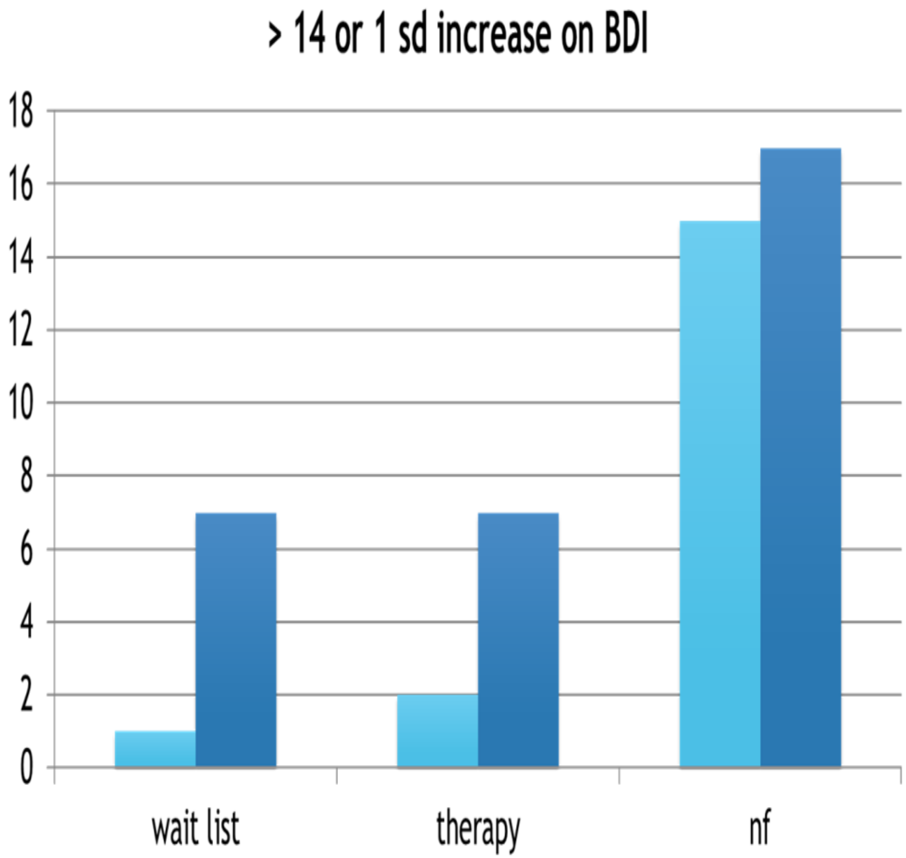


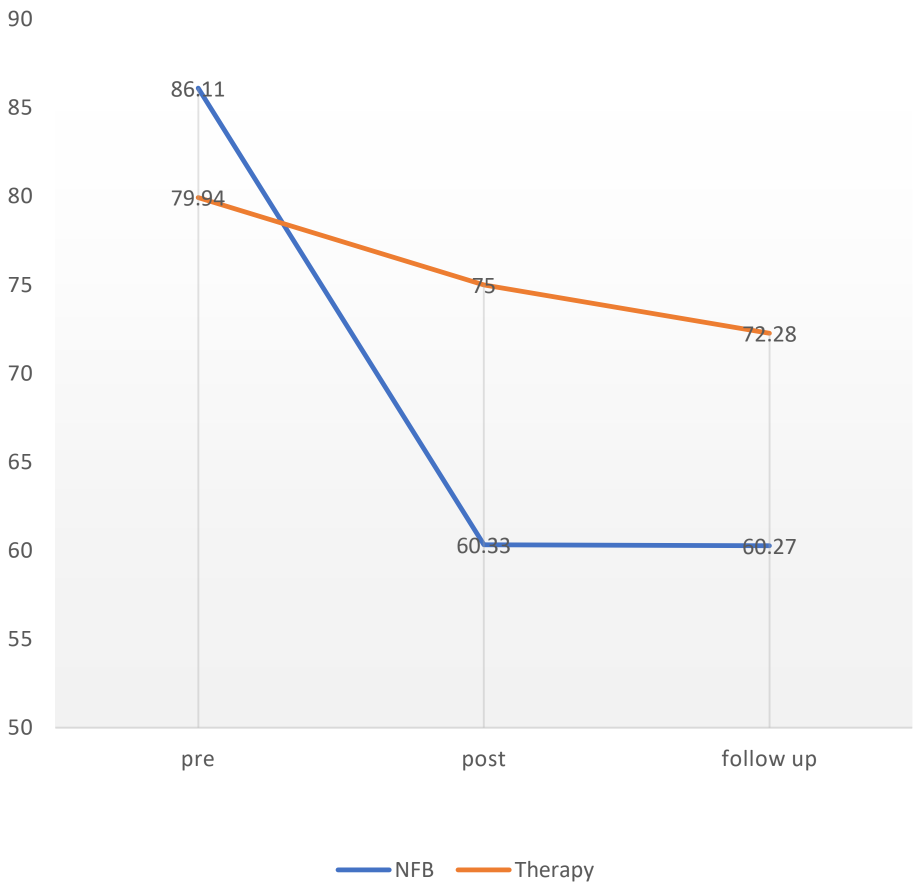
Depression Two Years Post Four Channel Multivariate Coherence Neurofeedback Treatment

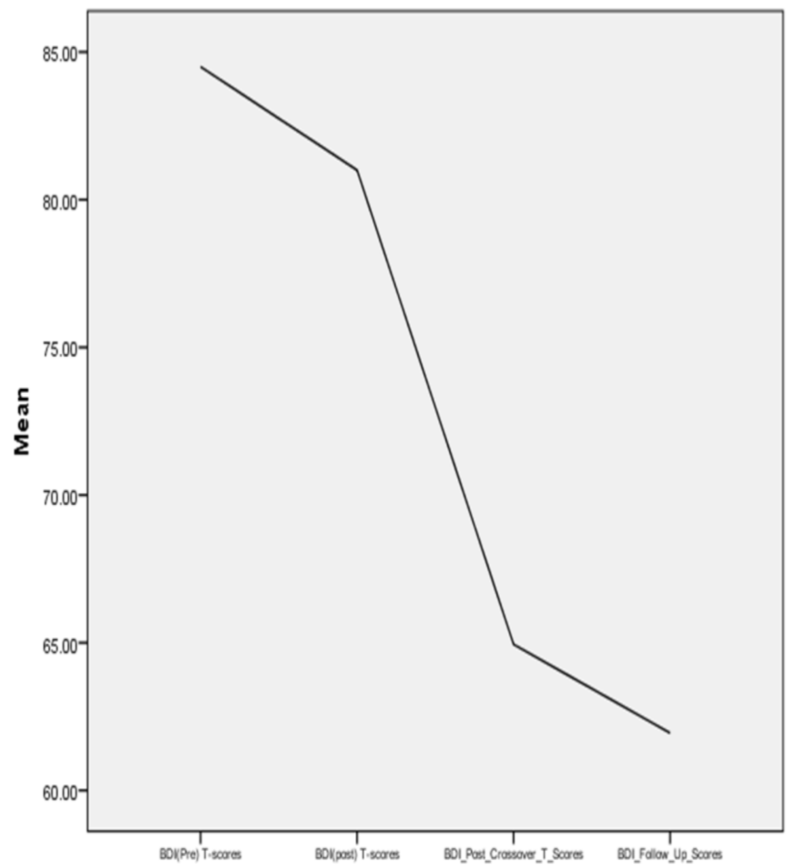
Abby Bolen, BA, BS, Caitlinn Mosley, BA, Robert Coben, PhD.

Presented at the 25th Annual ISNR Conference, September, 2017, Foxwoods, CT






90
85
80
75
70
65
60
55
50
86.11
79.94
75
72.28
60.33
60.27
pre
post
follow up
NFB
Therapy


Mean
85.00
80.00
75.00
70.00
65.00
60.00
BDI(Pre) T-scores
BDI(post) T-scores
BDI_Post_Crossover_T_Scores
BDI_Follow_Up_Scores