Meta-Analysis of 4-Channel Multivariate Coherence Neurofeedback Research

Robert Coben, PhD & Carl Armes, BS
Integrated Neuroscience Services

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 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

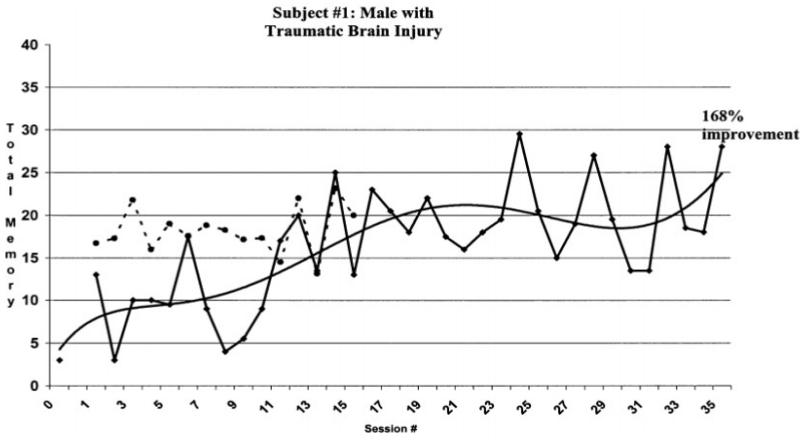


Fig 1. Undulating curve is a best-fit polynomial trend line to the 6th order. Dotted line = norms; Solid line = subject.

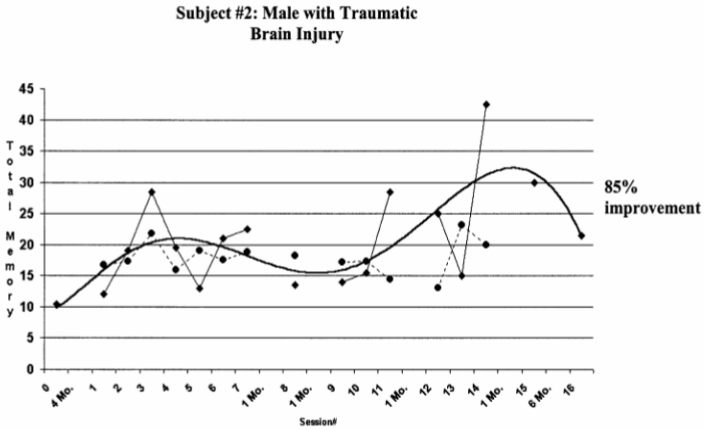


Fig 2. Undulating curve is a best-fit polynomial trend line to the 6th order. Dotted line = norms; Solid line = subject.

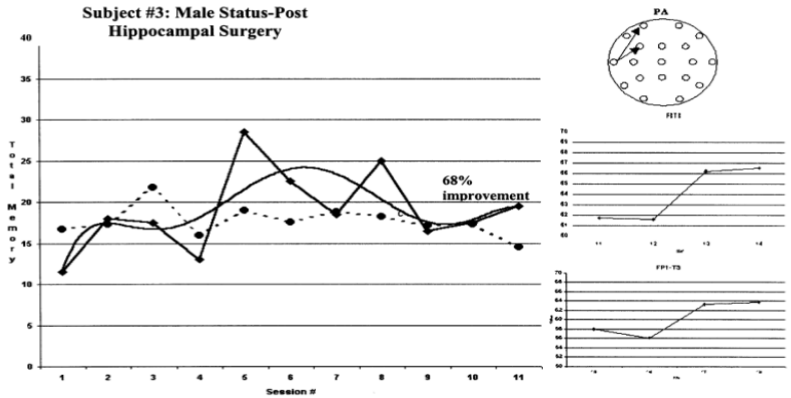


Fig 3. Undulating curve is a best-fit polynomial trend line to the 6th order. Dotted line = norms; Solid line = subject; PA = phase alpha.

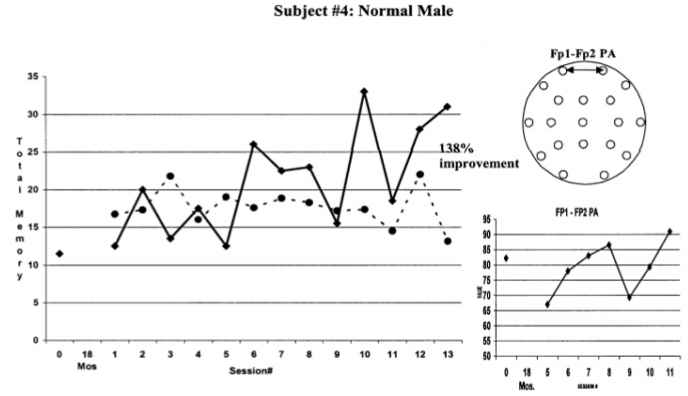


Fig 4. Undulating curve is a best-fit polynomial trend line to the 6th order. Dotted line = norms; Solid line = subject; PA = phase alpha.

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

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

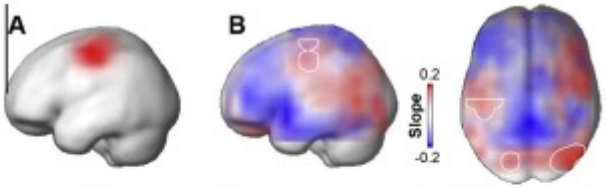
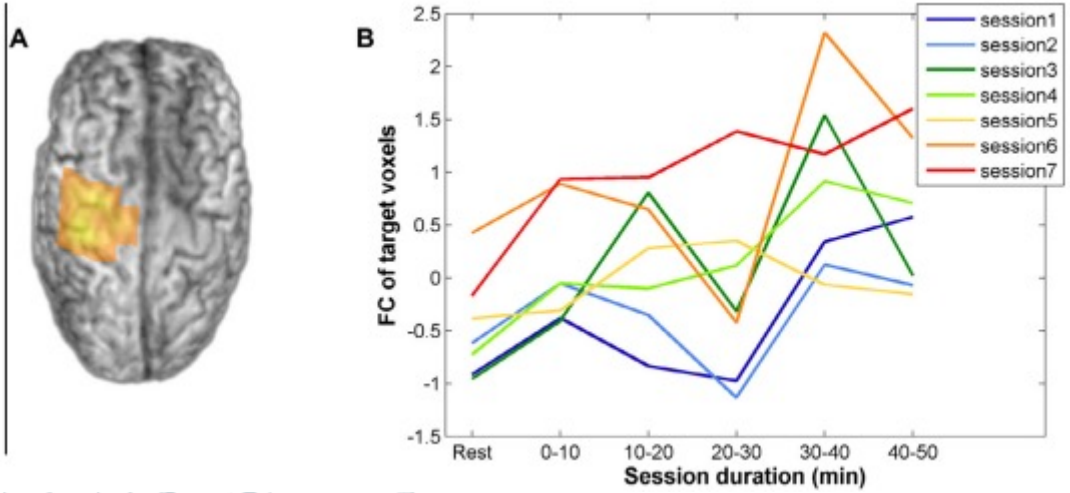


Fig. 2. Mean slope of alpha-band coherence evolution during neurofeedback training of 10 healthy subjects. Subjects tried to voluntarily enhance alpha-band coherence between the left or right hand motor cortex and the rest of the brain in a single session. Subjects with right target are flipped to left 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 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

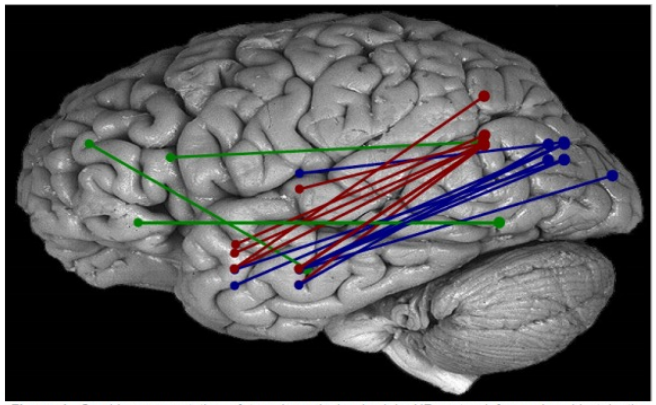


Figure 1. Graphic representation of two-channels involved in NF protocol for each subject in the experimental group. Represented are those trained from occipital-temporal (blue), parietal-temporal (red), and temporal-parietal-frontal (green).

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

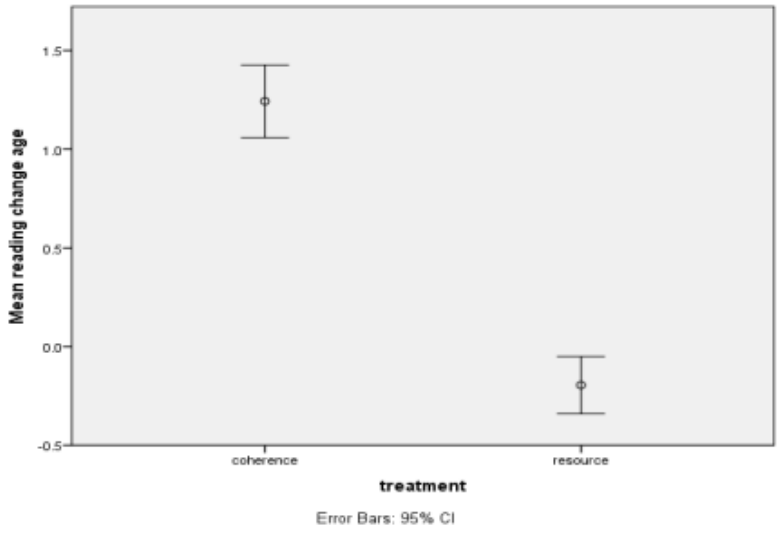


Figure 2. Change in age equivalent reading scores by group.

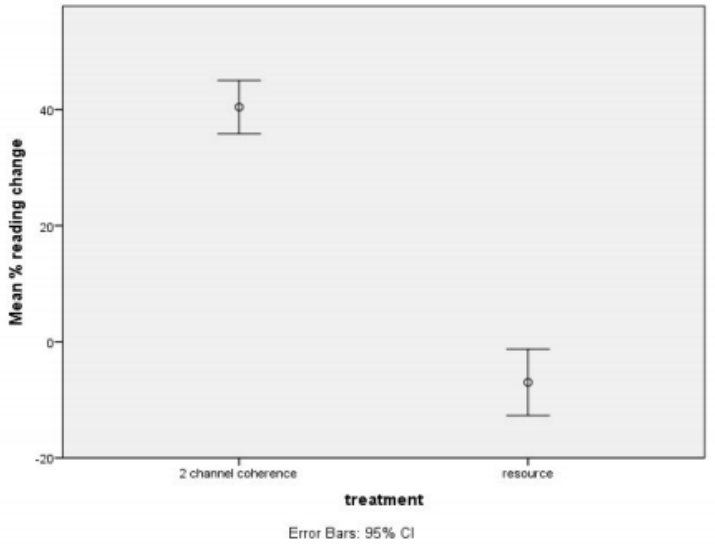


Figure 3: Change in percentage reading delay by group.

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

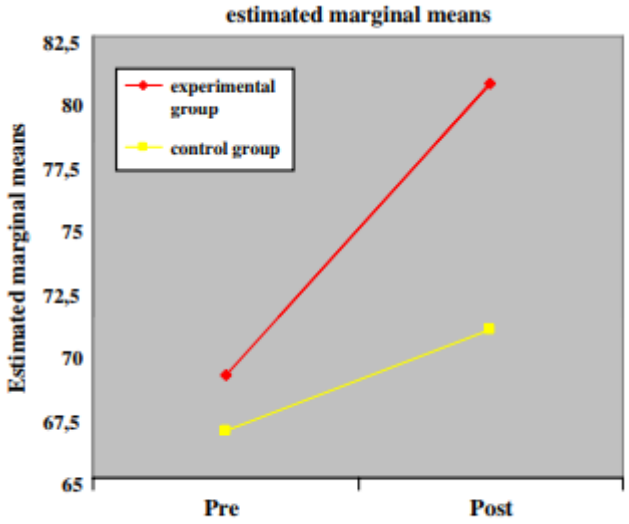
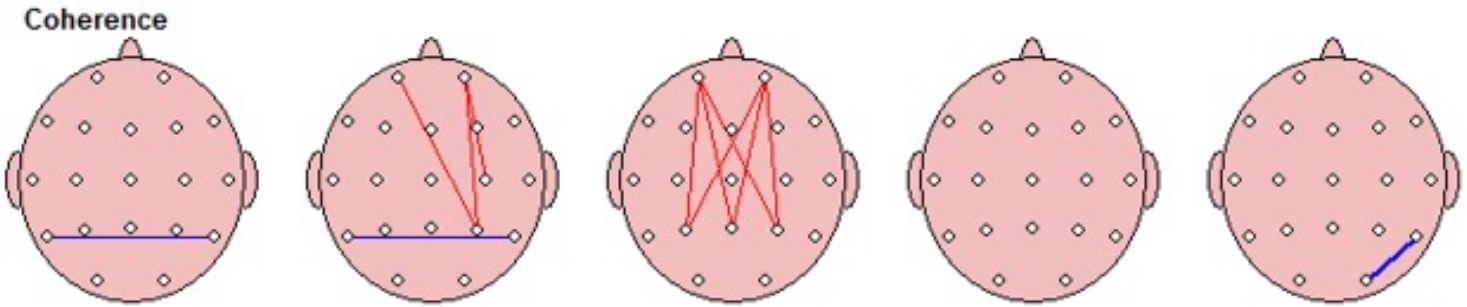


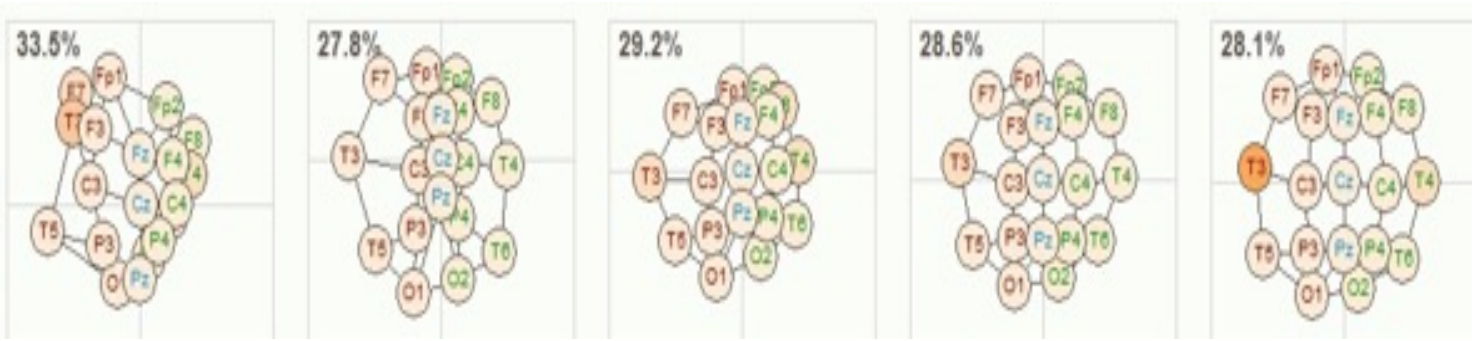
Fig. 1 Pre- and posttest scores on spelling test

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





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			

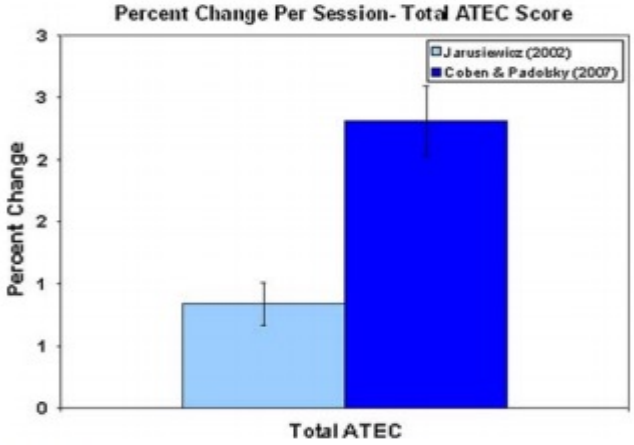


Fig. 5 The amount of change in Total ATEC scores per session was significantly greater in Coben and Padolsky (2007) than the amount of change per session in Jarusiewicz (2002)

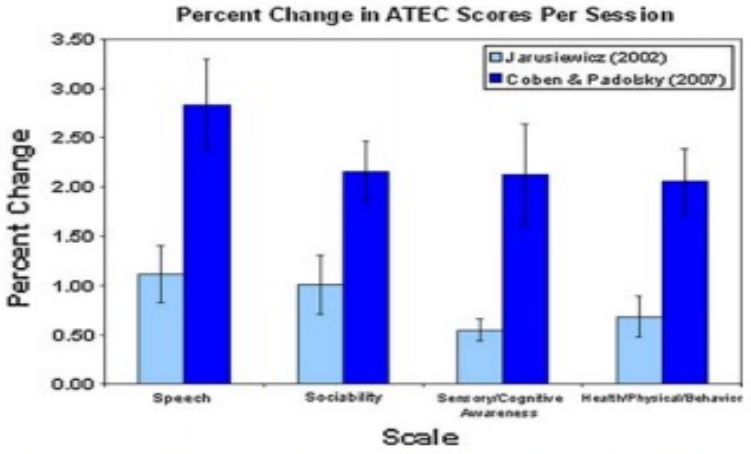
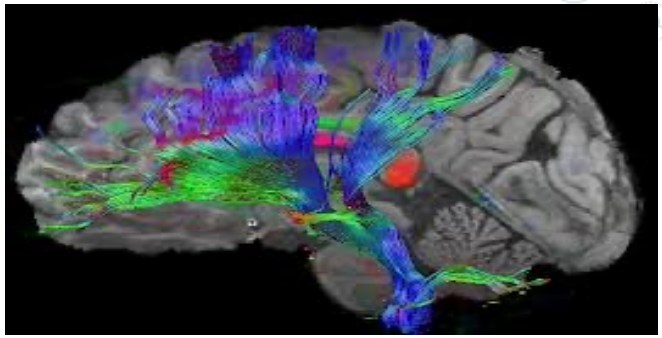
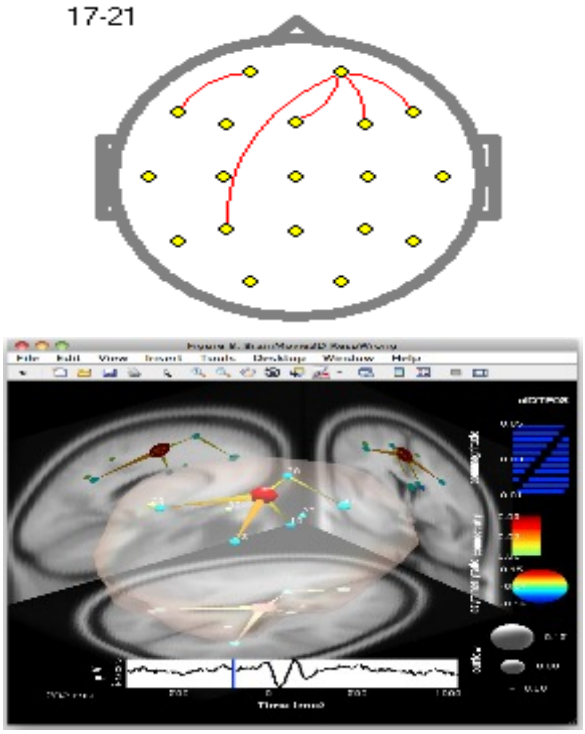


Fig. 4 The amount of change which occurred per session in Coben and Padolsky (2007) was significantly greater than the amount of change which occurred per session in Jarusiewicz (2002) for all subscales of the ATEC

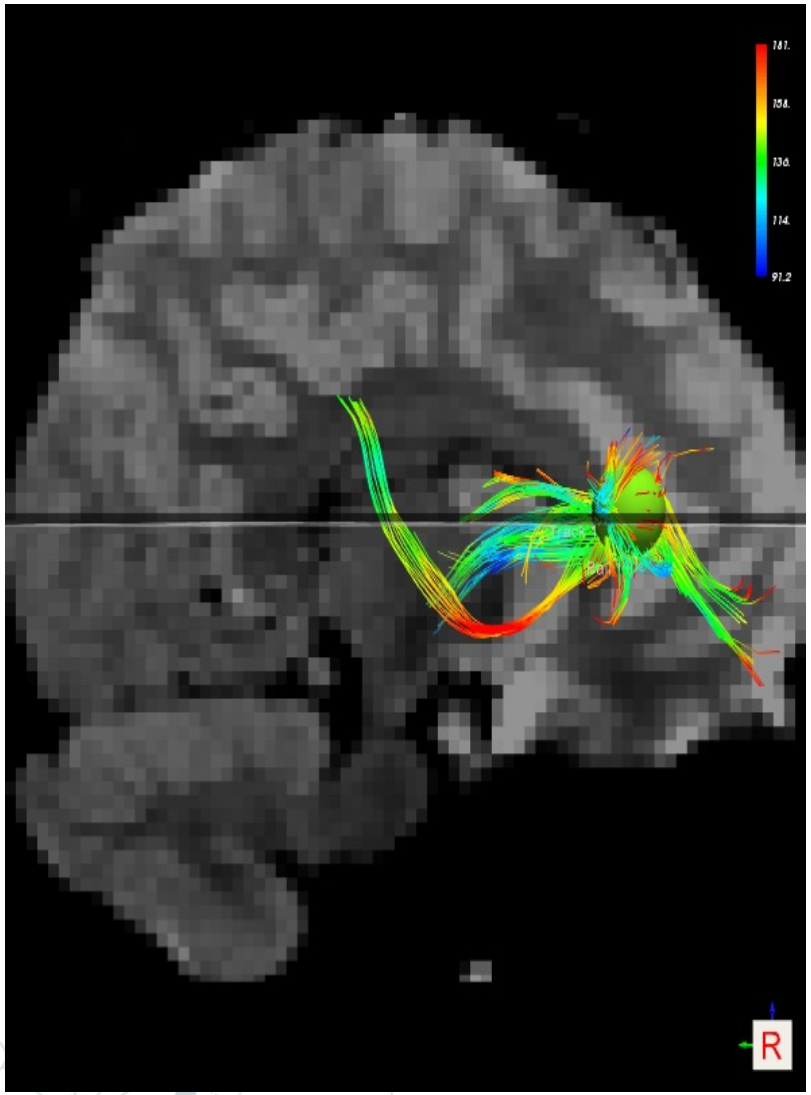
Types of connectivity

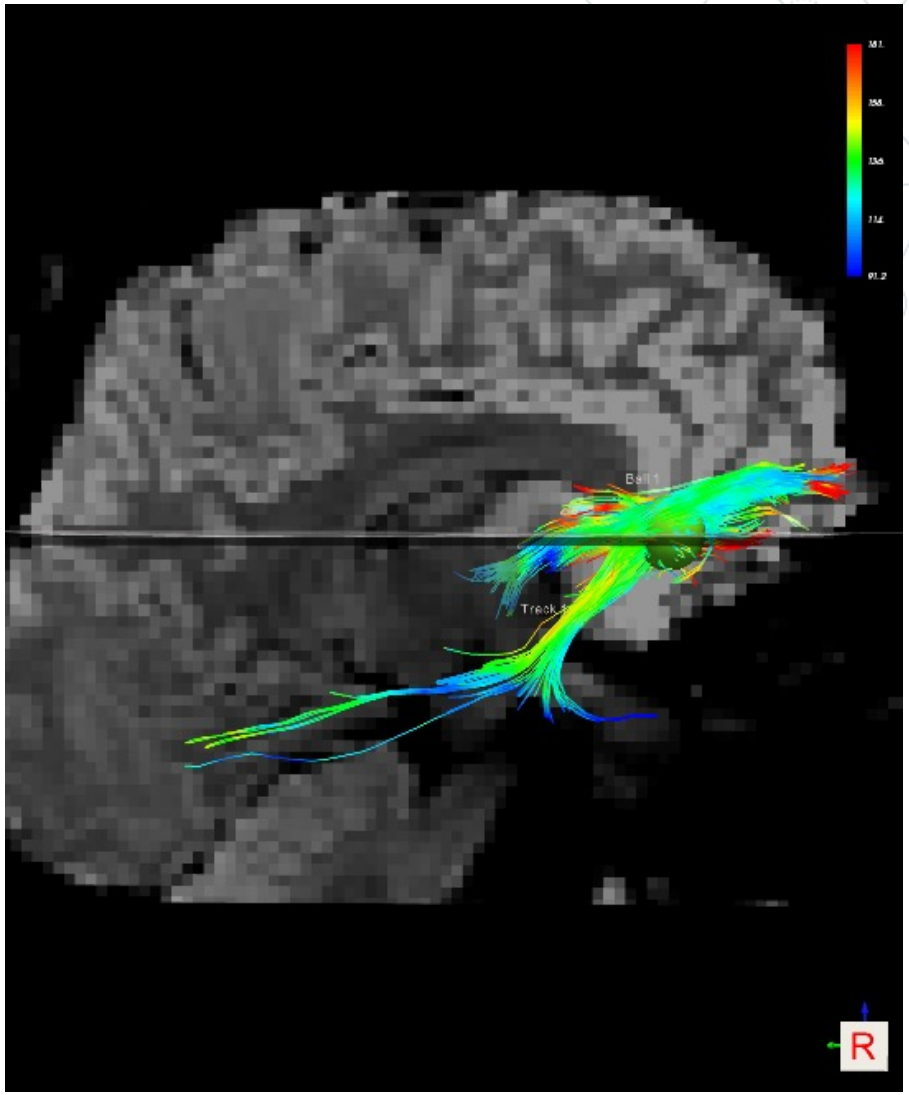
- Structural connectivity
- Functional connectivity
- Effective connectivity

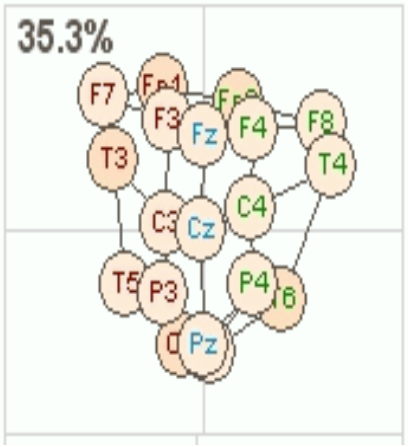


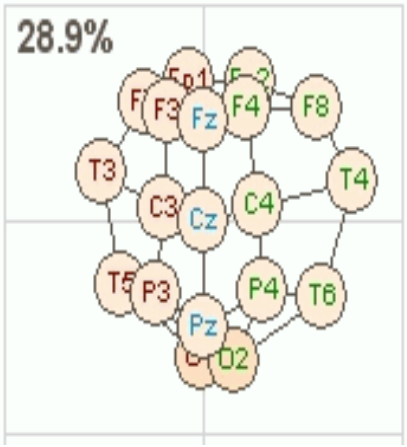


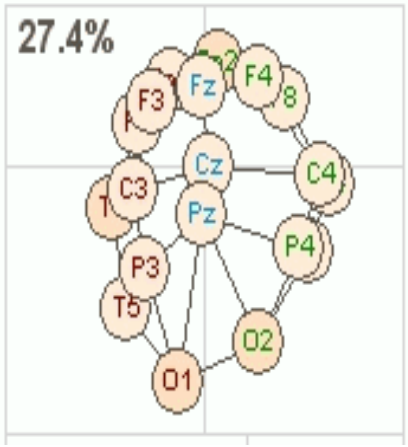
Comparing DTI to Coherence measurements

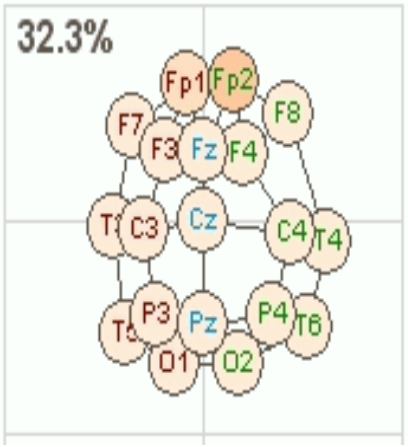


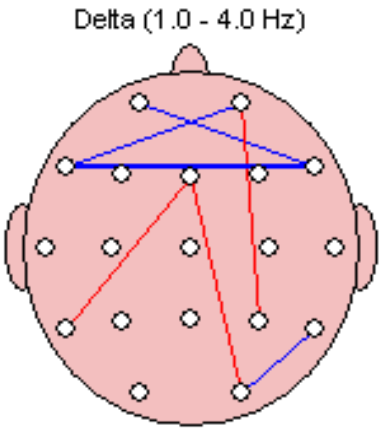


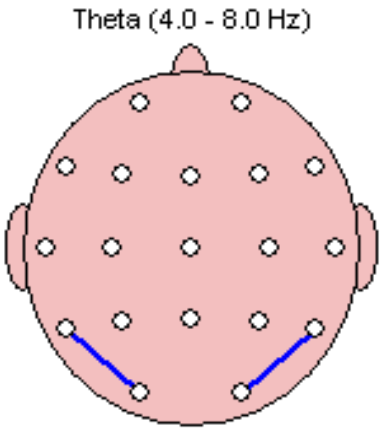

35.3%
F7
F3
Fz
F4
F8
T3
C3
Cz
C4
T4
T5
P3
P4
Pz

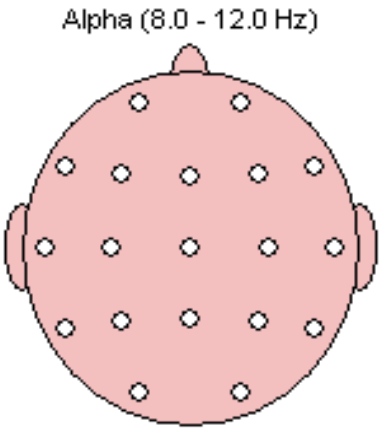

28.9%
F3
Fz
F4
F8
T3
C3
Cz
C4
T4
T5
P3
P4
T6
Pz
O2

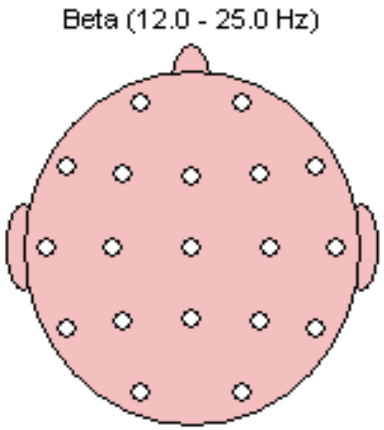

27.4%
F3
Fz
F4
Cz
C4
C3
Pz
P4
P3
T5
O2
O1


32.3%
Fp1
Fp2
F7
F8
F3
Fz
F4
C3
Cz
C4
T4
P3
Pz
P4
T6
O1
O2


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

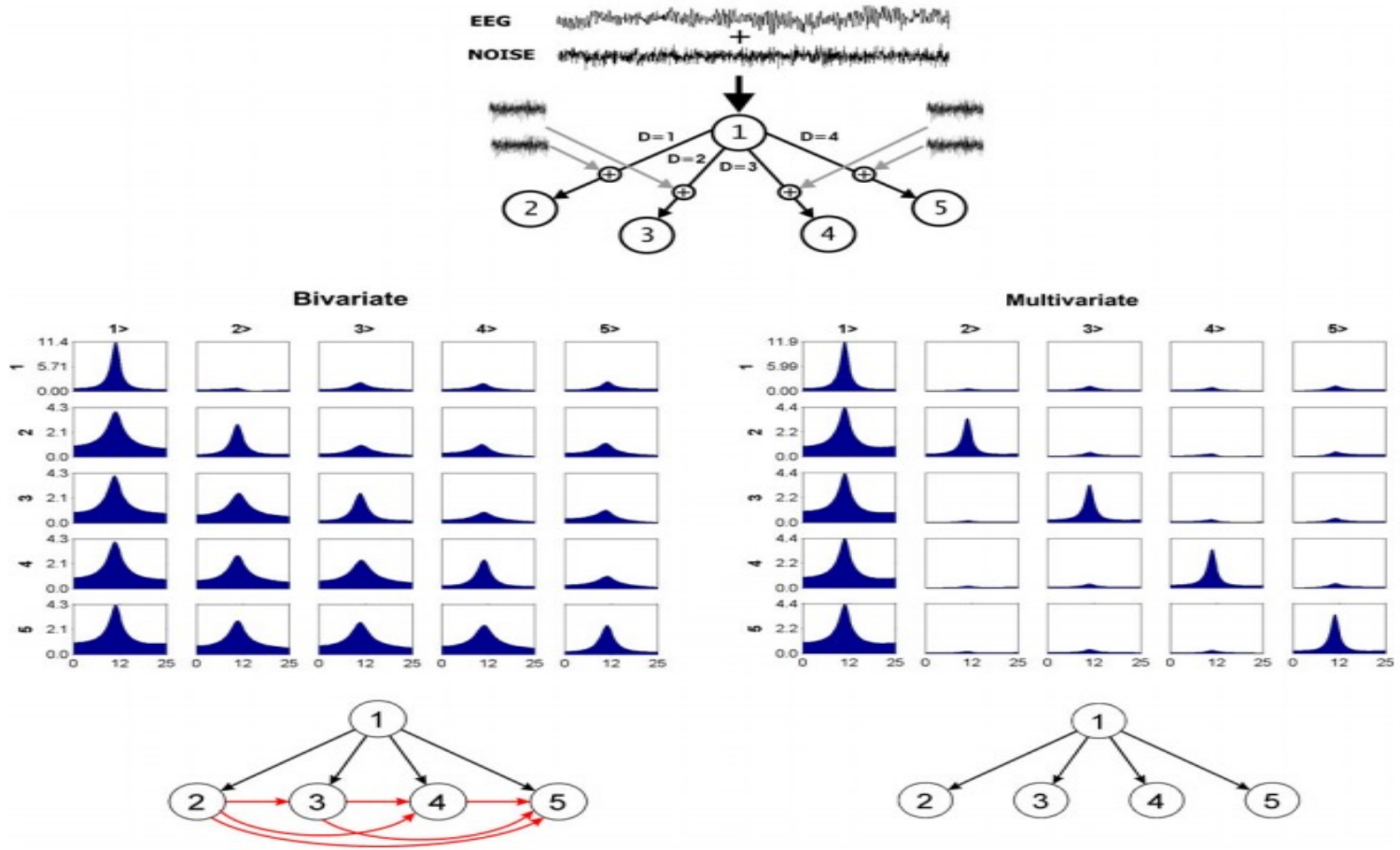
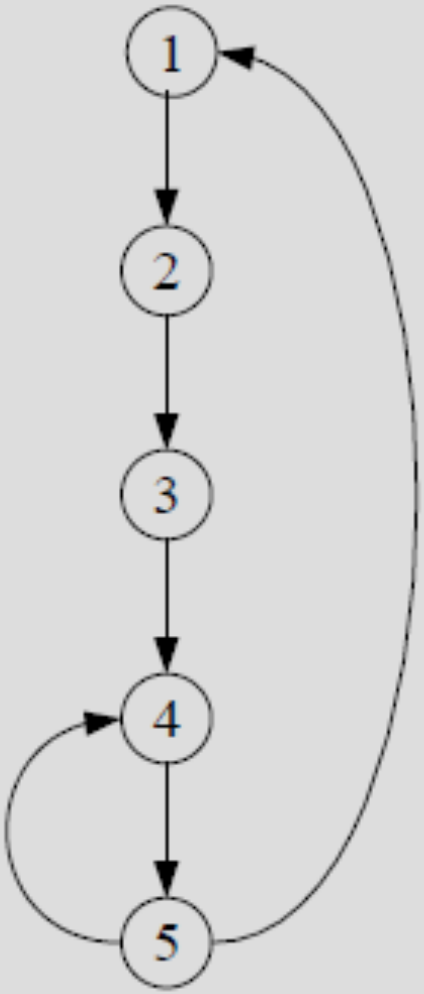
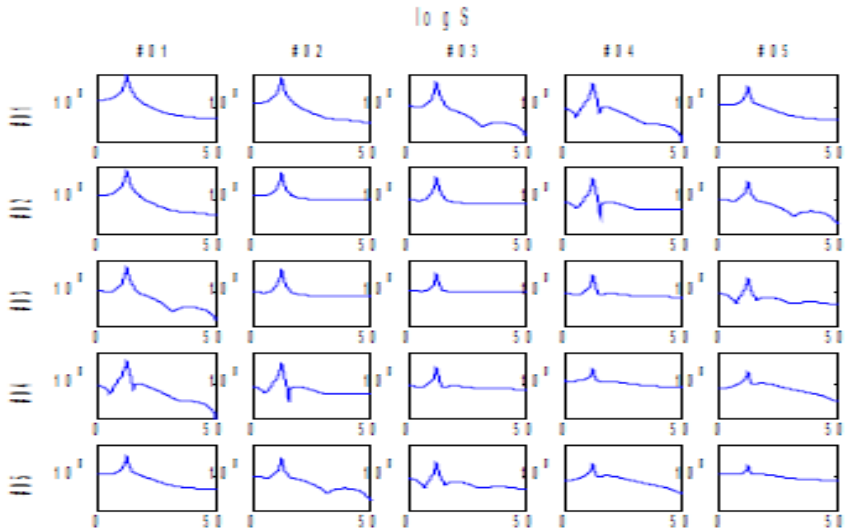


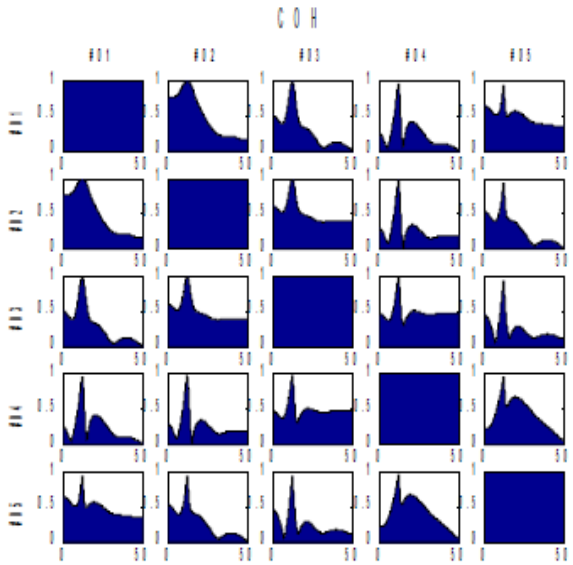
Fig. 1 Comparison of bivariate and multivariate methods of estimation of directed connectivity. *Top* simulation scheme (*D* delay value, at each step white noise is added). *Bottom* connectivity measures, at the *left* bivariate, at the *right* multivariate. Propagation from the channel marked above 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

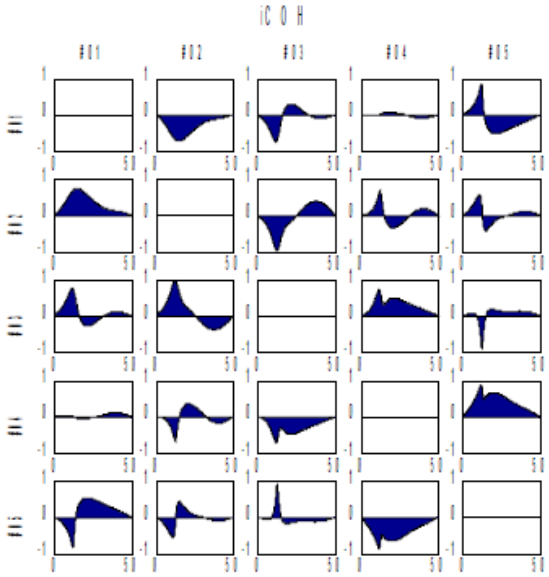


Auto- & Crossspectra

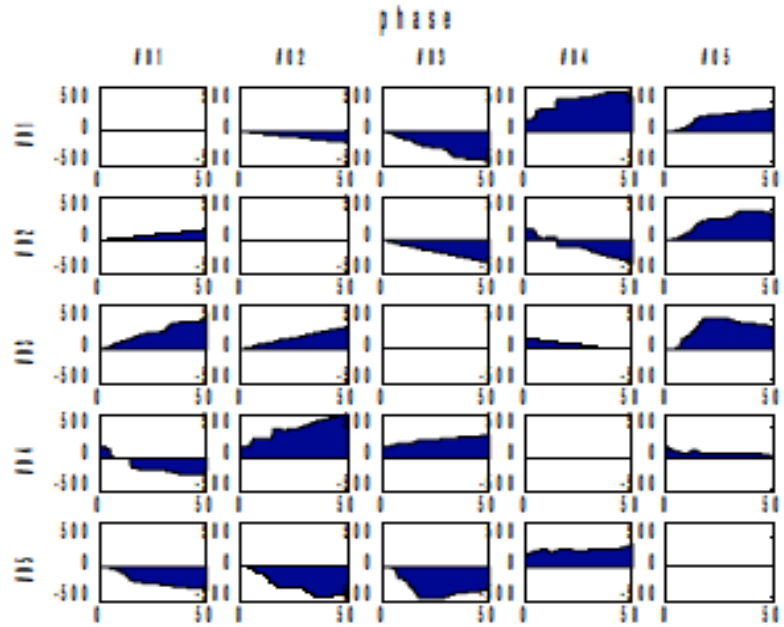


Coherency, Coherence (COH)

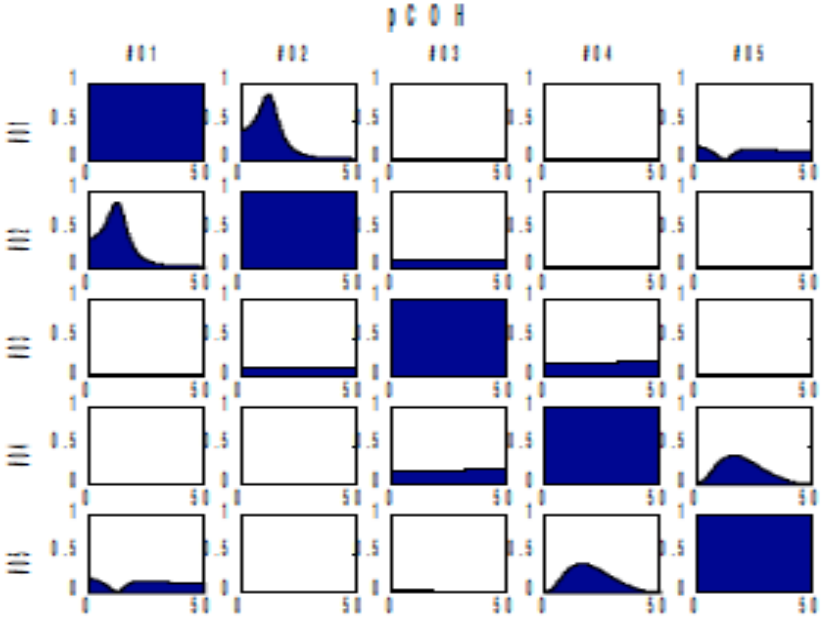




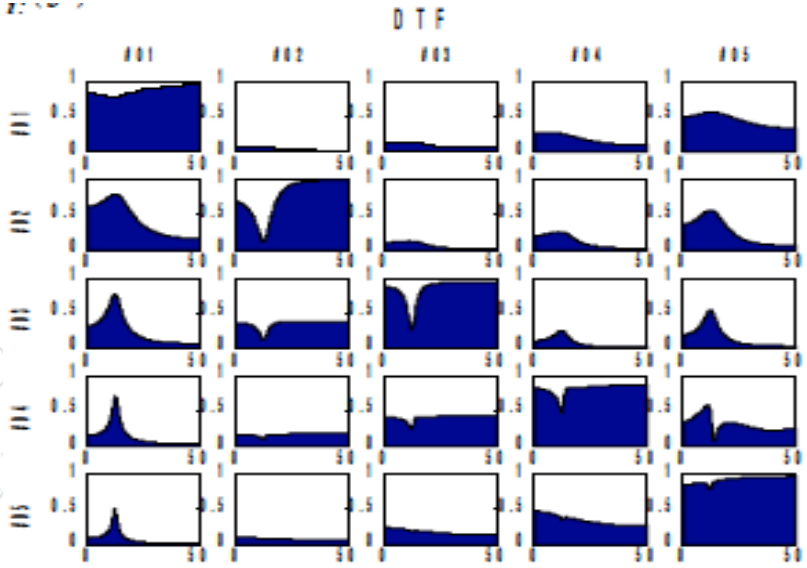
Phase differences and time delay



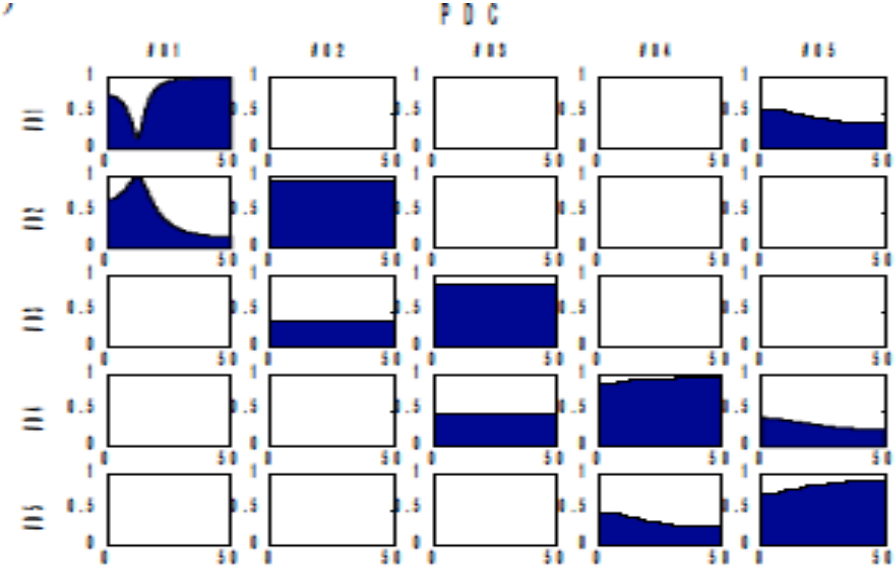
partial Coherence (pCOH)



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**

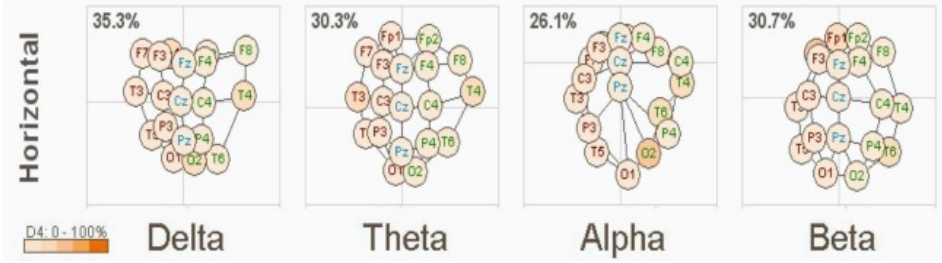


FIGURE 1 | NeuroRep Multivariate Connectivity analyses showing eigen images in the horizontal place across delta, theta, alpha, and beta frequencies. Observable features include; (1) right hemisphere (temporal) hypocoherences across all frequency bands, (2) hypercoherences in the alpha band over prefrontal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

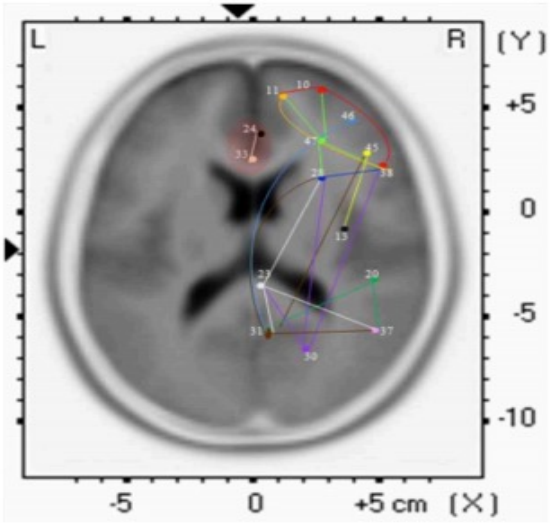


FIGURE 3 | Each of the 15 ROIs for this case study are represented in a different color. The lines indicate significant correlations between the colored ROI and other regions. The color of the line is the same as the ROI in relation to its functional connectivity with other ROIs.

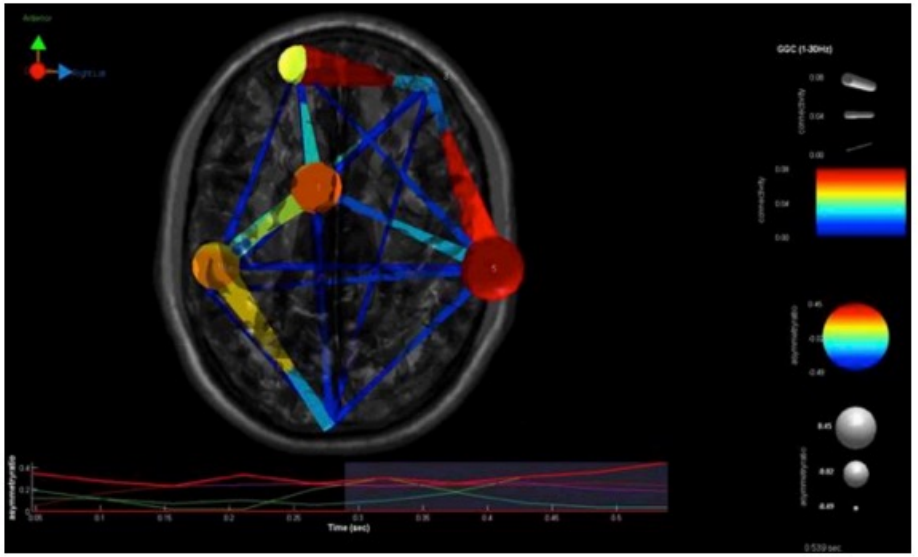
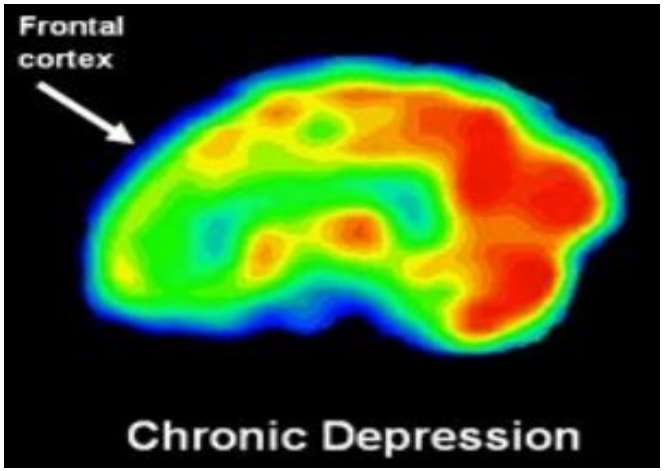
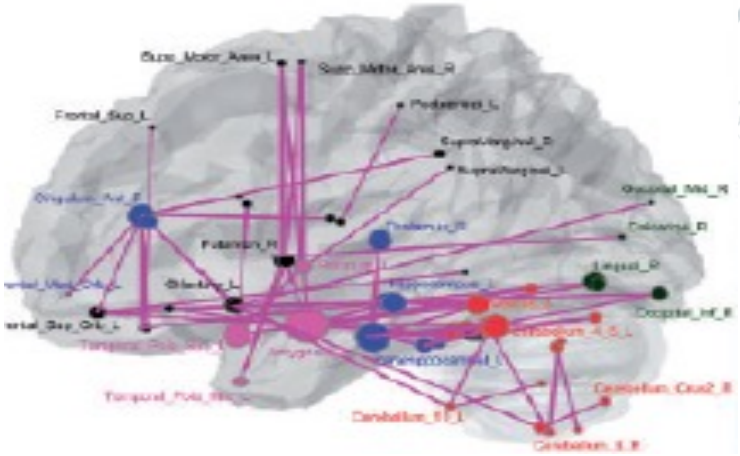
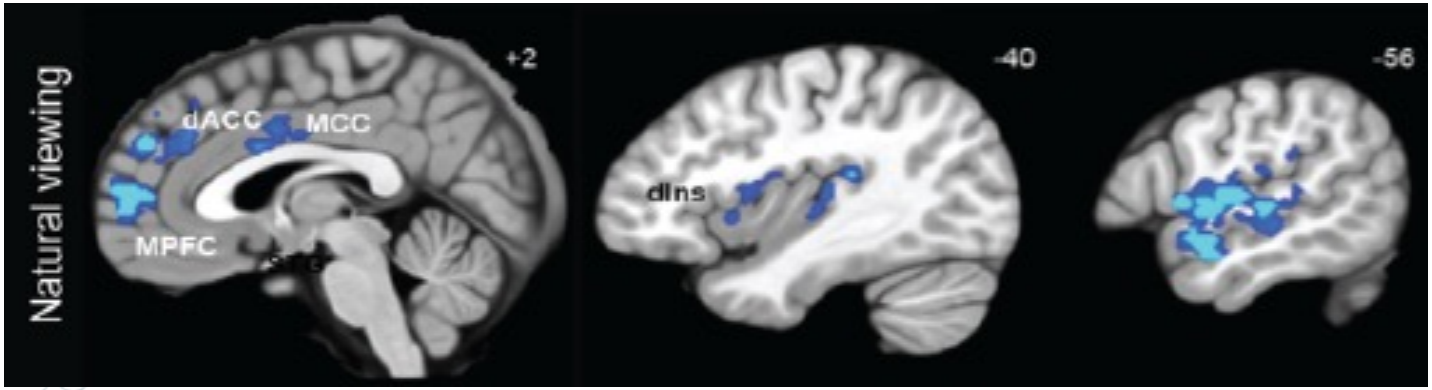


FIGURE 5 | SIFT/Granger (GGC) causality brain image. Levels of greater connectivity are shown with thicker lines and brighter colors. Direction of causality is indicated by the key in the upper left hand corner. ICs and their localization are listed as part of **Table 3**.

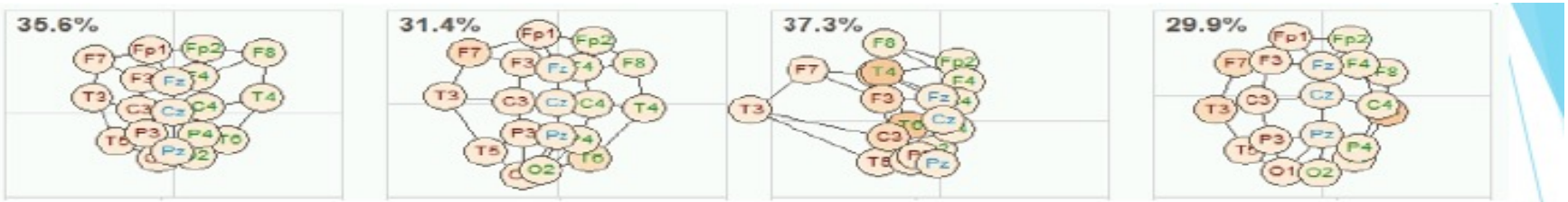
Exemplar: Major Depression

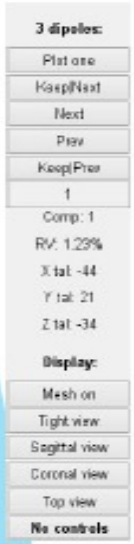


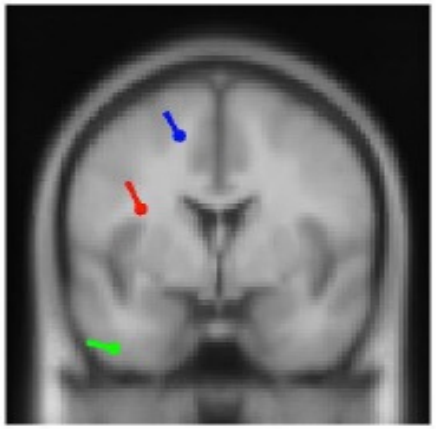


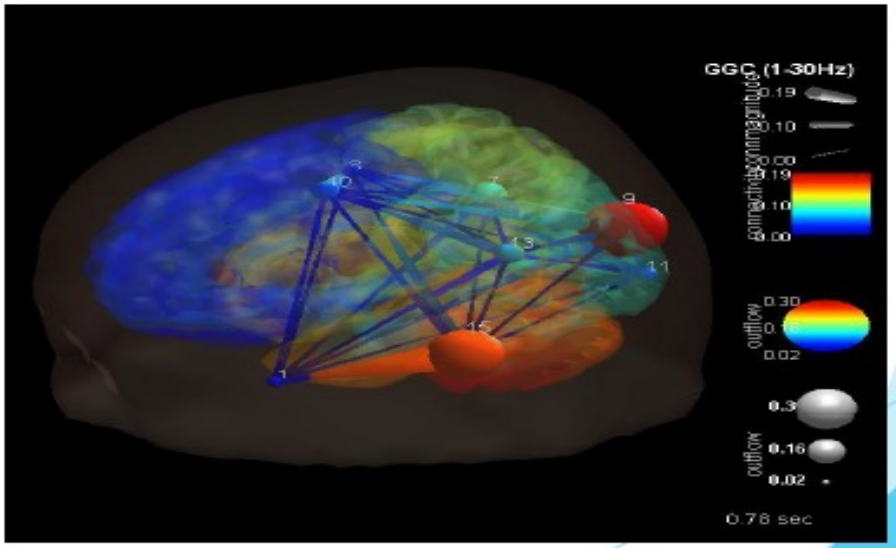


Exemplar: Major Depression









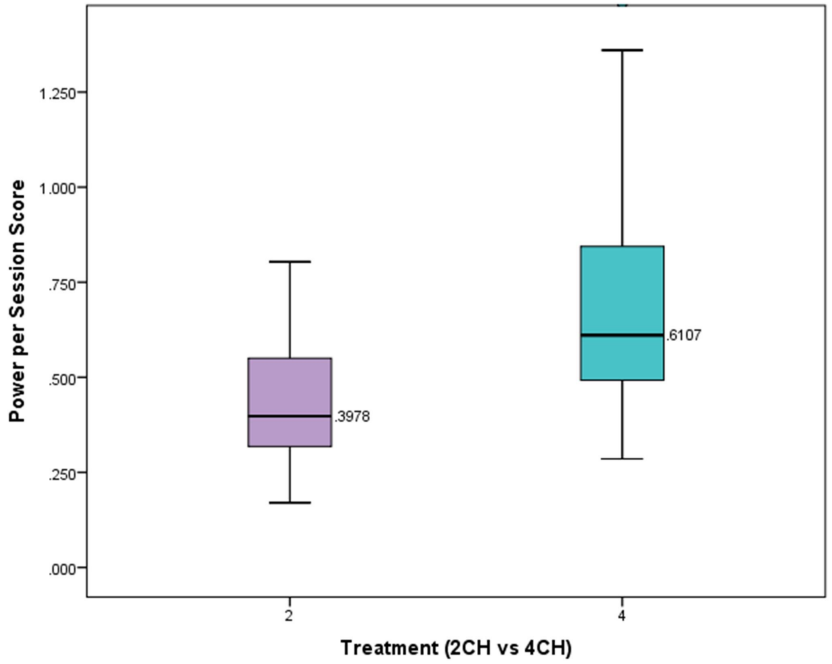
TECHNOLOGY REPORT ARTICLE

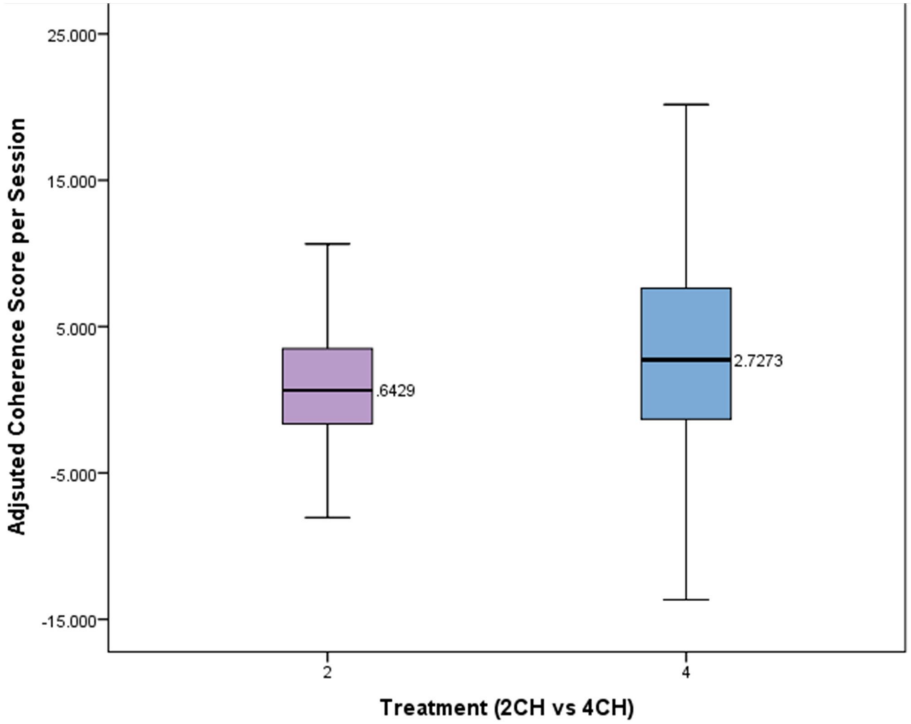
Front. Neurosci., 11 October 2018 | https://doi.org/10.3389/fnins.2018.00729

Four Channel Multivariate Coherence Training: Development and Evidence in Support of a New Form of Neurofeedback


Robert Coben[1]*, Morgan Middlebrooks[1], Howard Lightstone[2] and Madeleine Corbell[3]

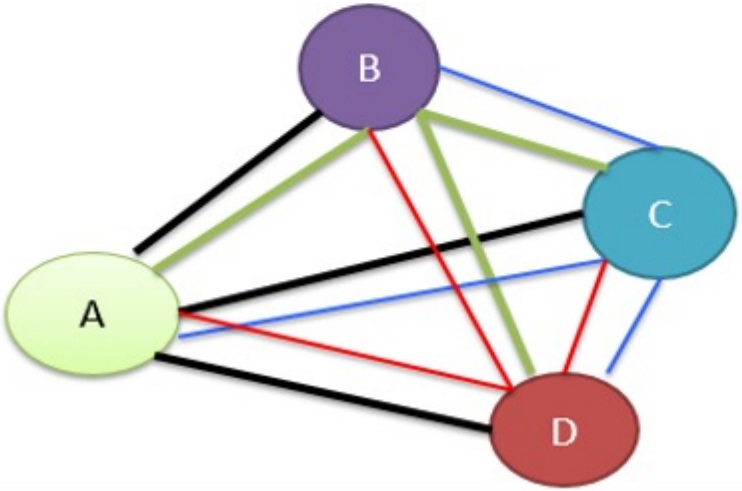
[1]Integrated Neuroscience Services, Fayetteville, AR, United States
[2]EEG Software, LLC, Gainesville, FL, United States
[3]Department of Psychological Science, University of Arkansas, Fayetteville, AR, United States





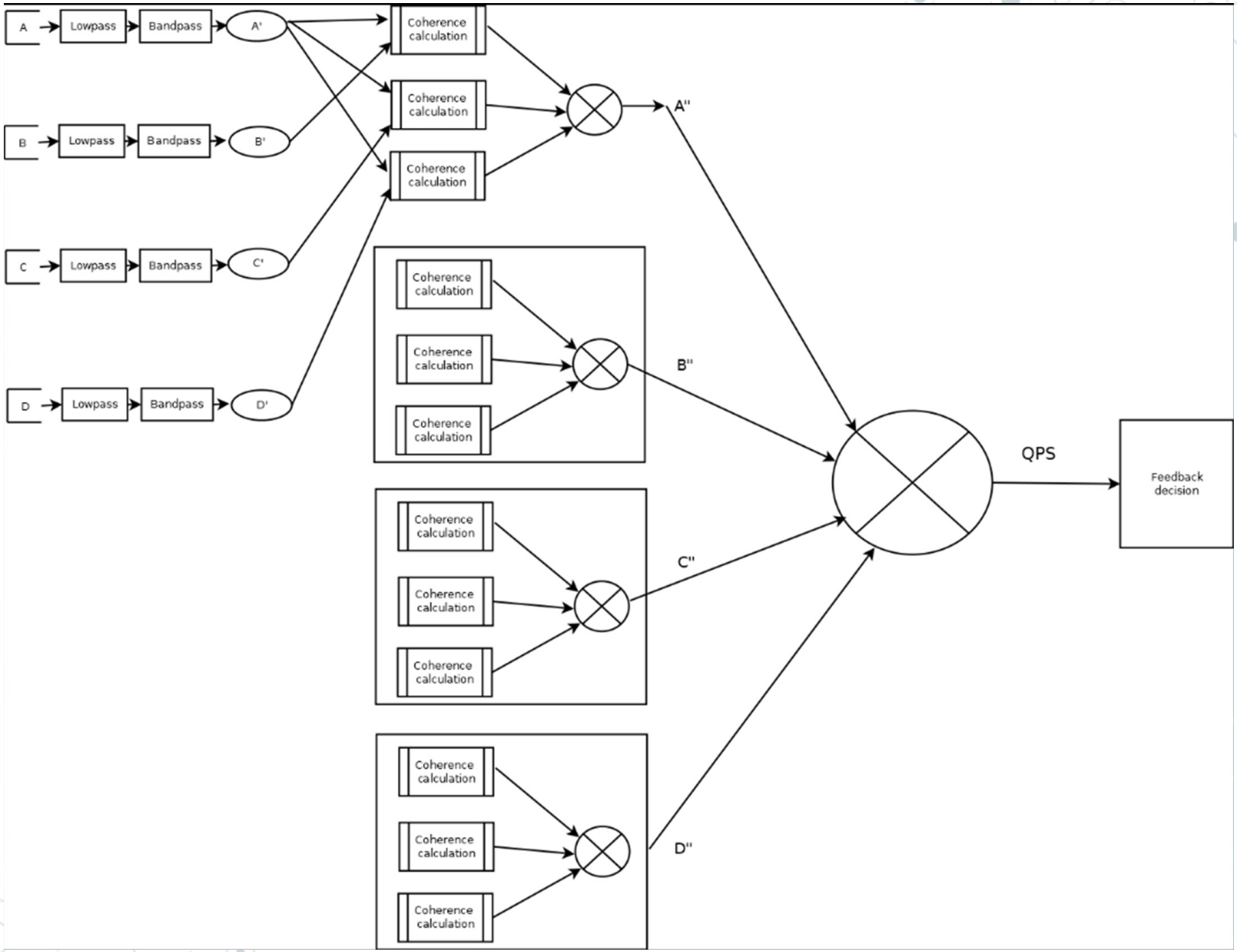
QPS: Averaging coherences

- 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


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

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

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

compute Avg like submode AVG

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

Anecdotal evidence

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

Efficacy Studies in Support of 4 channel MVCNF (N = 591)

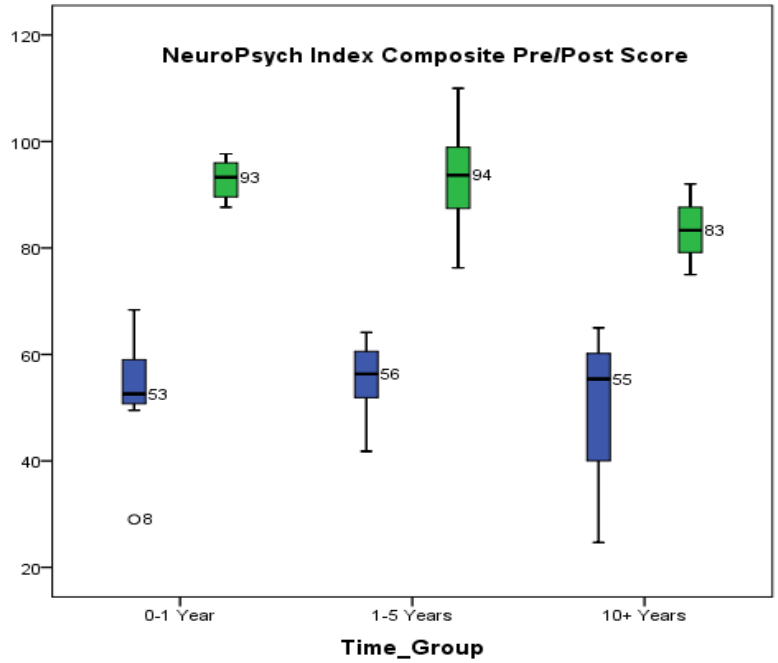
Population	Sample	Design	Findings 1	Findings 2
General Population	N = 174	MVCNF v 2 Ch CNF	MVCNF > 2 Ch CNF	Enhanced coherence and reduced power
Traumatic Brain Injury	N = 20	Compared time since injury in 3 groups	Improvements in symptoms and NP testing	Changes associated with increases in coherence
Epilepsy	N = 52	MVCNF v 2 Ch CNF	MVCNF > 2 Ch CNF	81% reduction in seizures
Learning Disabilities	N = 63	MVCNF v 2 ch CNF v resource room	MVCNF > 2 ChCNF > RR	1.6 year increase in reading
Autism	N = 110	MVCNF v 2 Ch CNF	MVCNF > 2 Ch CNF	98% success rate
Autism MND	N = 78	MVCNF v 2 Ch CNF v Bipolar	MVCNF > 2 ChCNF > Bipolar	Mu suppression with coherence changes
Depression	N = 54	MVCNF Psychotherapy v WLC	MVCNF > both groups	94% success rate, crossover and 2 yr f/u
Developmental Trauma	N = 40	MVCNF v. Psychotherapy	Exp > controls on clinical ratings	Δ in power, sources and connectivity

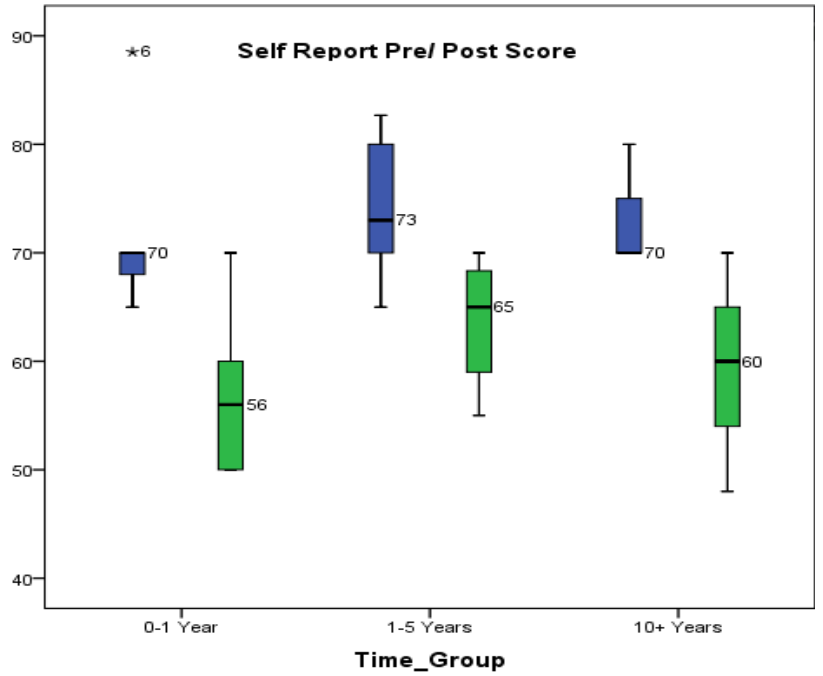
The Use of Four Channel Multivariate coherence Training on Mild Traumatic Brain Injury:

A comparison of newly concussed and remotely concussed individuals

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

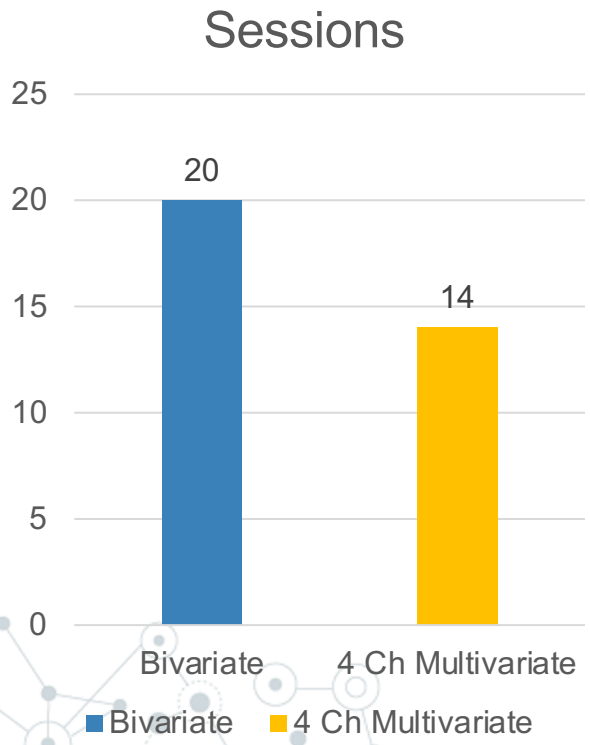
Anne Stevens, Ph.D., Morgan Middlebrooks, BA
Integrated Neuroscience Services, Fayetteville, Arkansas

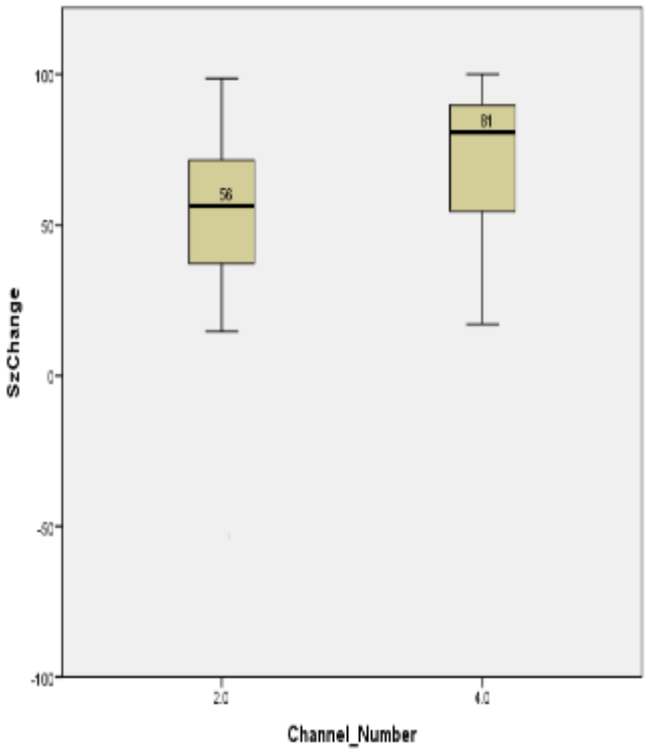


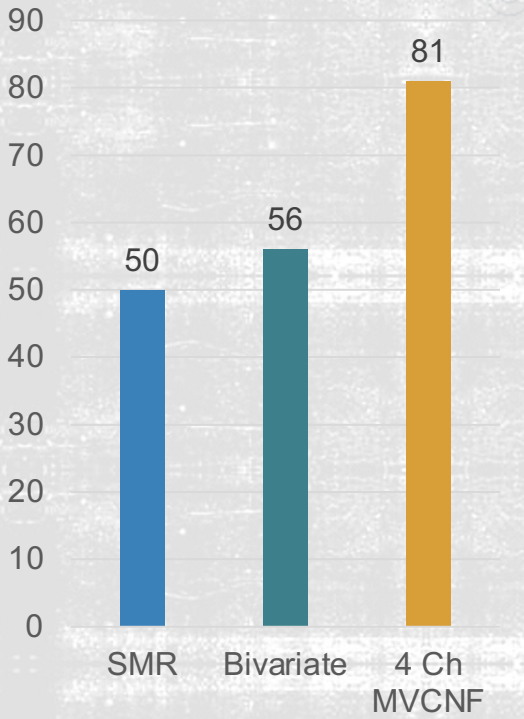


Relative efficacy of two different forms of Coherence Neurofeedback for Seizure Disorders

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

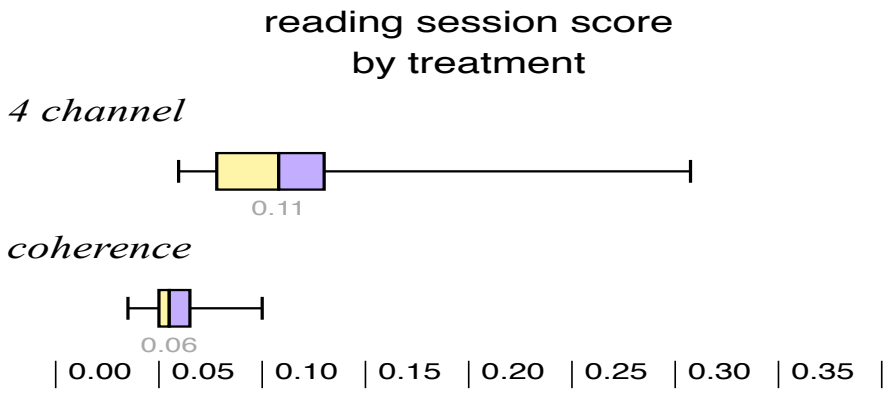






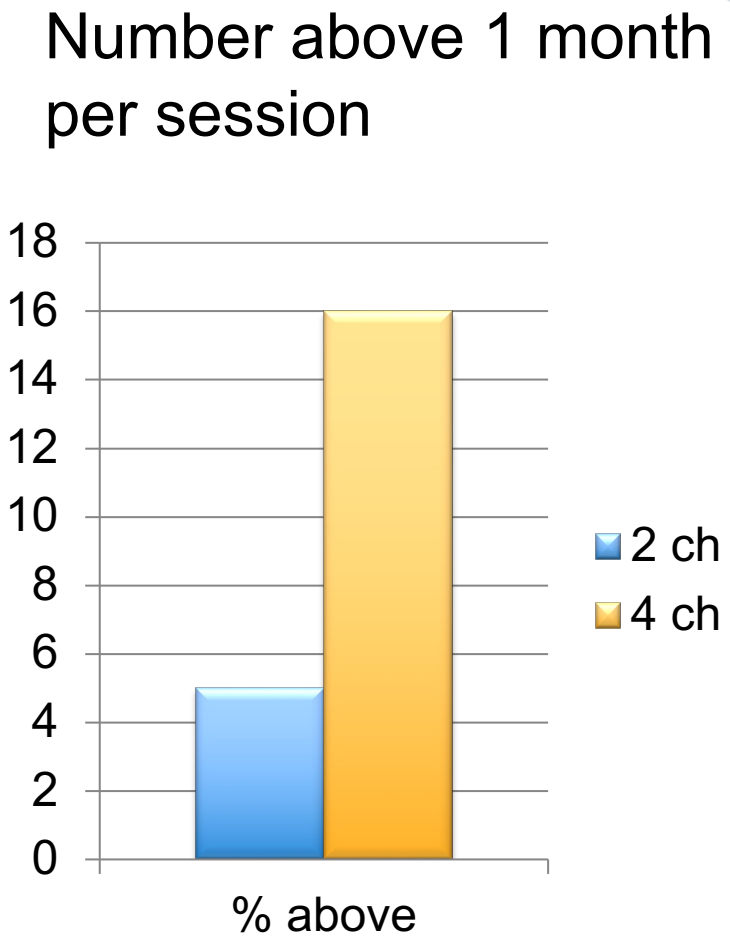
Controlled Analysis of EEG Coherence and it's impact on Learning Disabilities

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



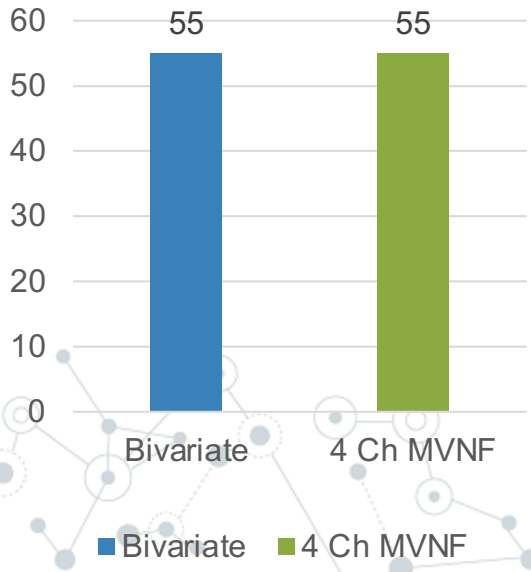
Group Statistics

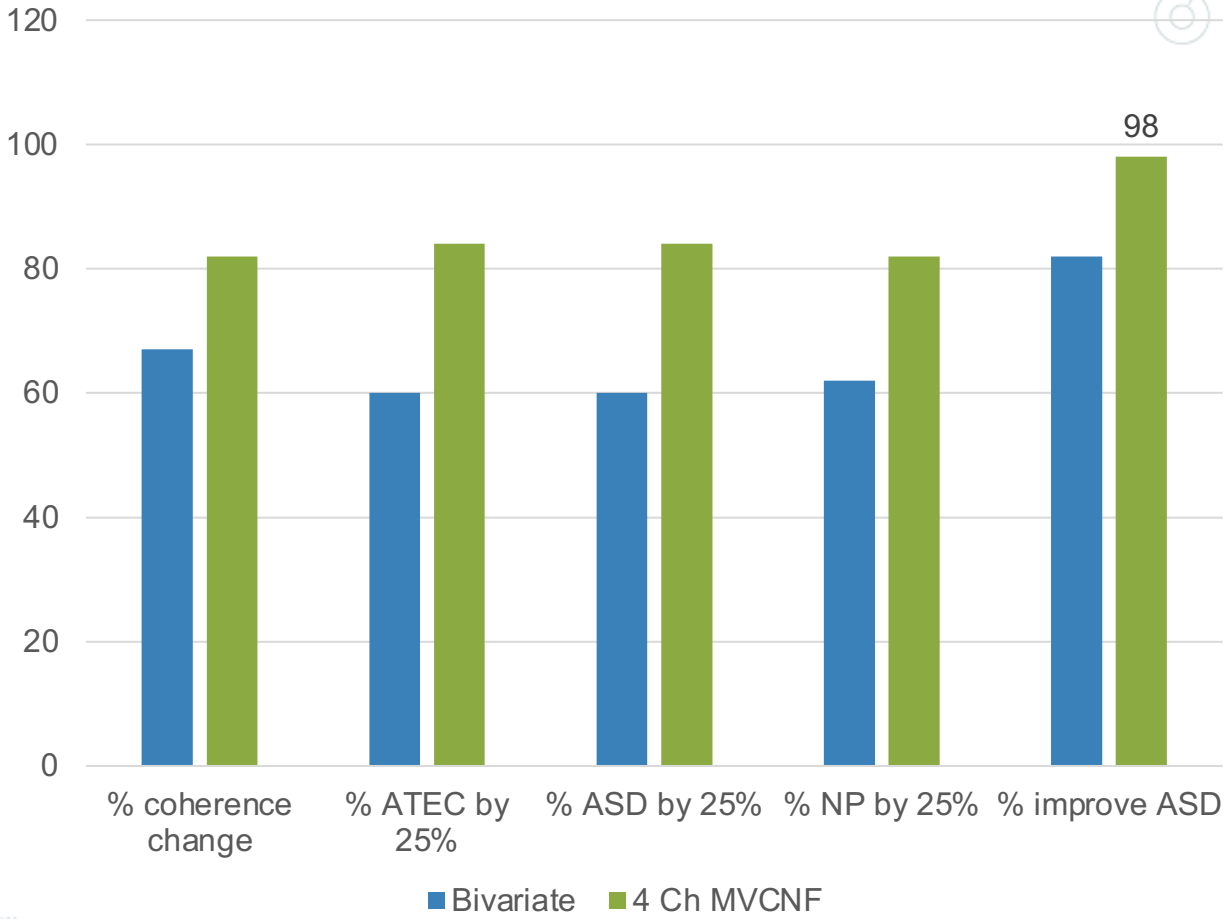
	treatment	N	Mean	Std. Deviation	Std. Error Mean
reading change age	two channel	21	1.243	.4044	.0883
	4 channel	21	1.628	.8313	.1814



Comparing Bivariate and Multivariate Coherence Neurofeedback for Autism Spectrum Disorder

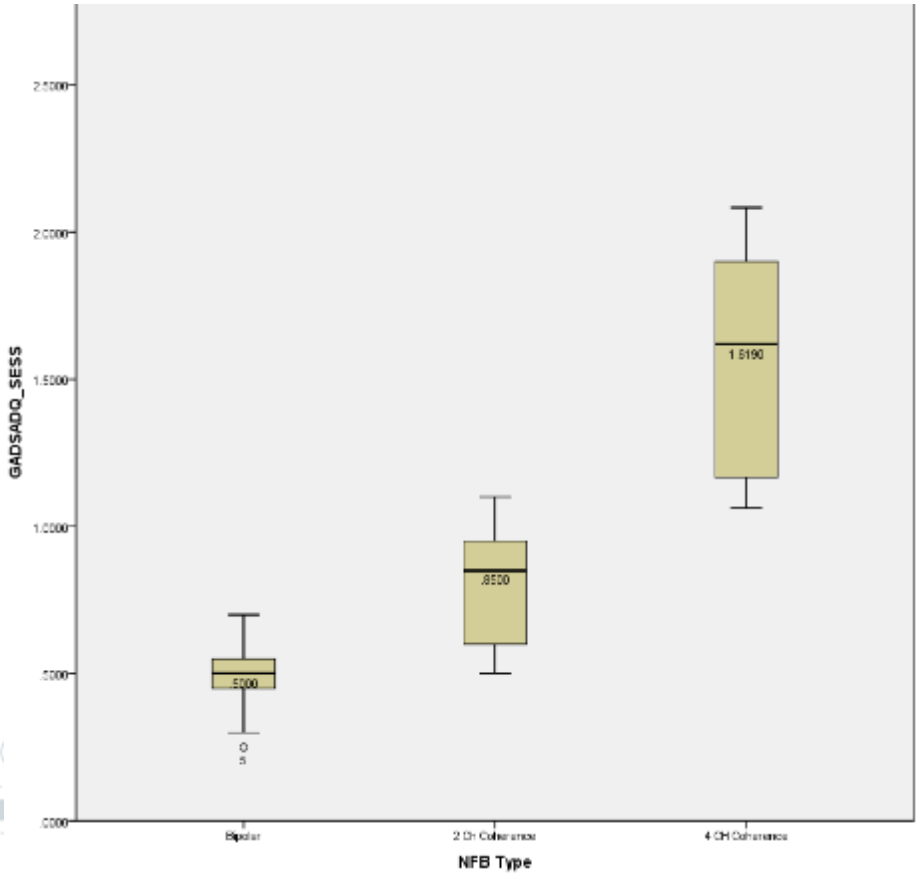
Robert Coben, PhD and Morgan Middlebrooks, BA

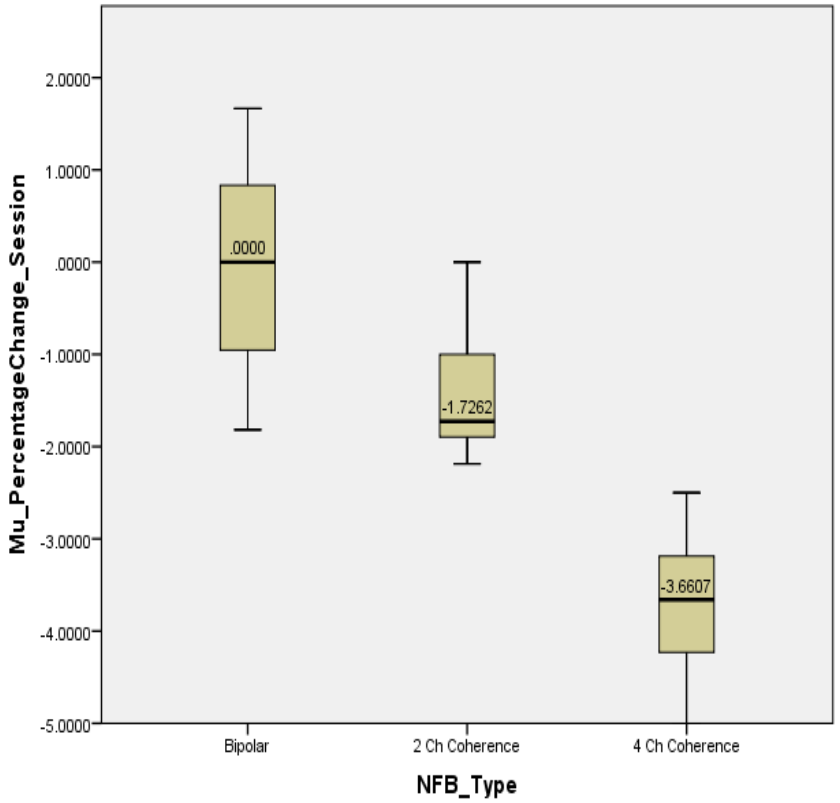


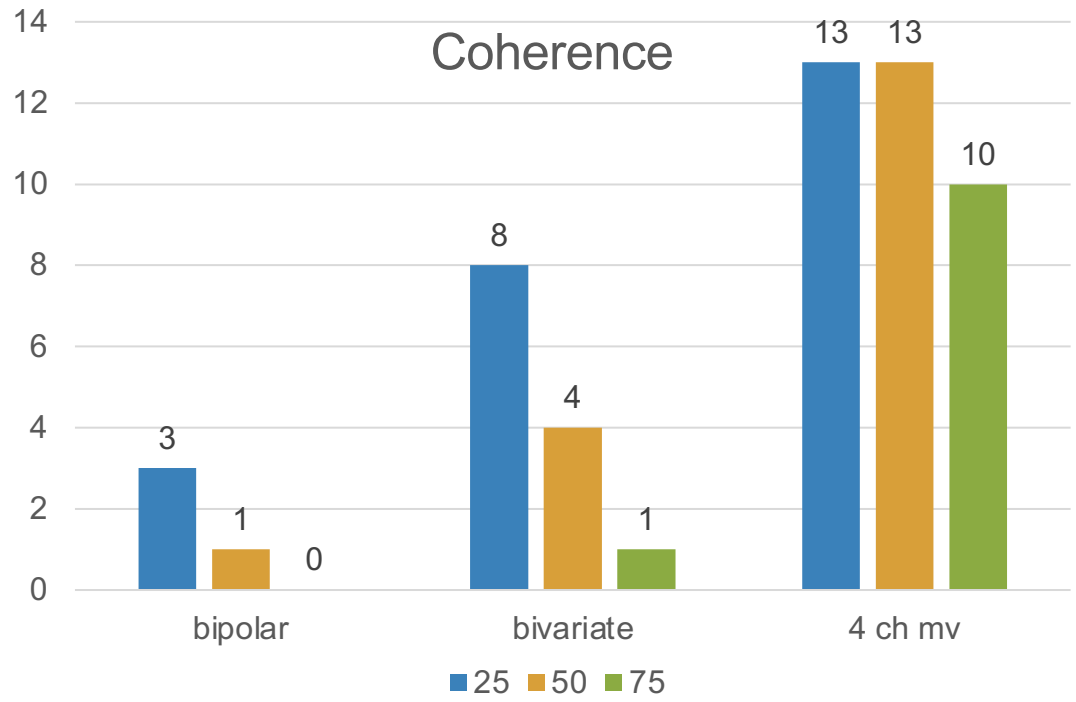


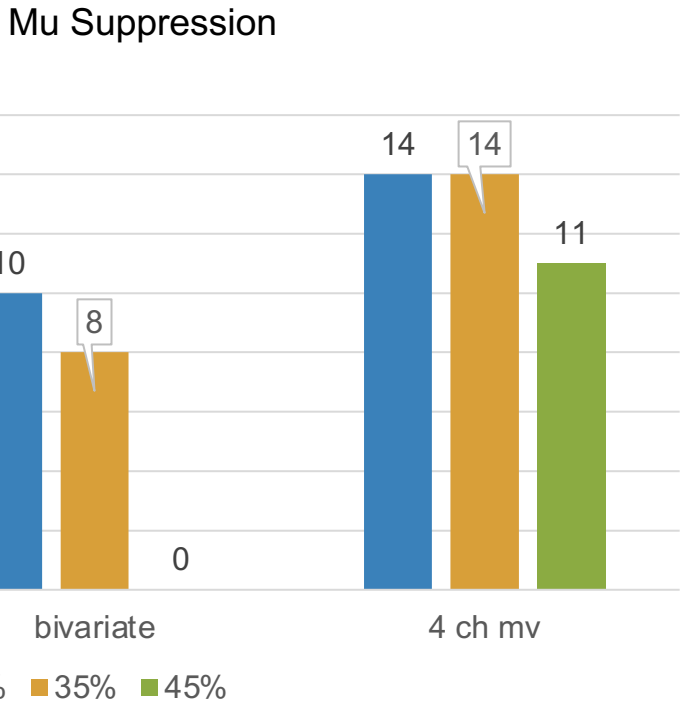
Exploring the impact of single channel, bivariate and multichannel coherence training on Mu suppression deficits in Autism Spectrum Disorders

Janease Traylor, MS and Robert Coben, PhD





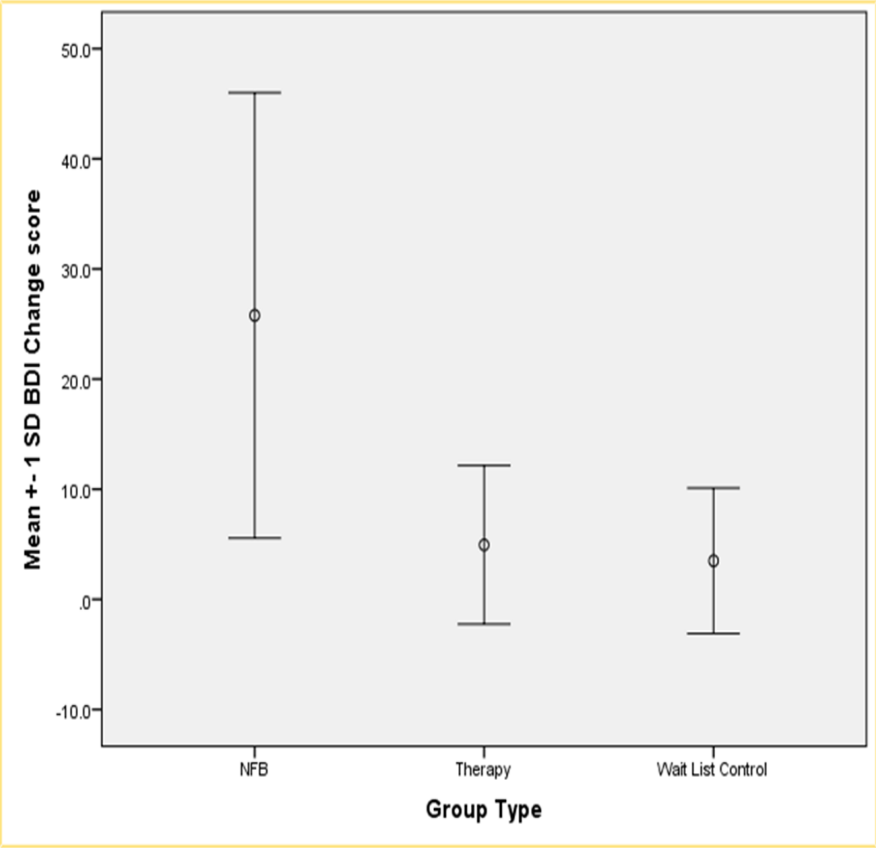

Coherence
14
12
10
8
6
4
2
0
3
1
0
8
4
1
13
13
10
bipolar
bivariate
4 ch mv
25
50
75

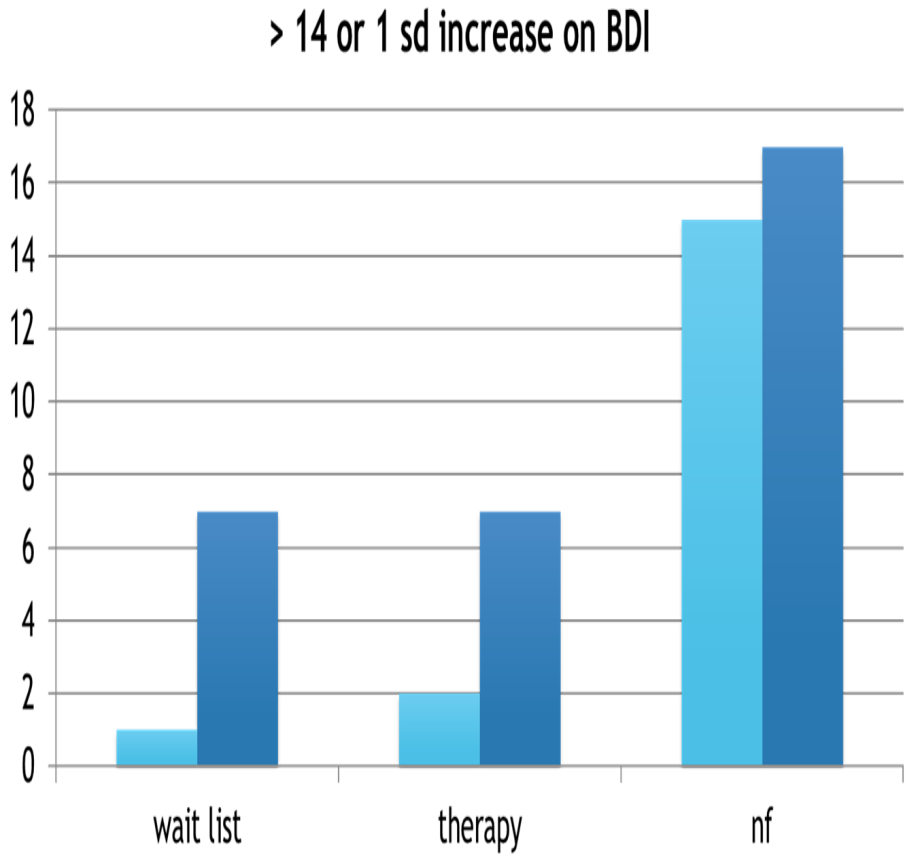

Mu Suppression
16
14
12
10
8
6
4
2
0
2
2
0
10
8
0
14
14
11
bipolar
bivariate
4 ch mv
25%
35%
45%

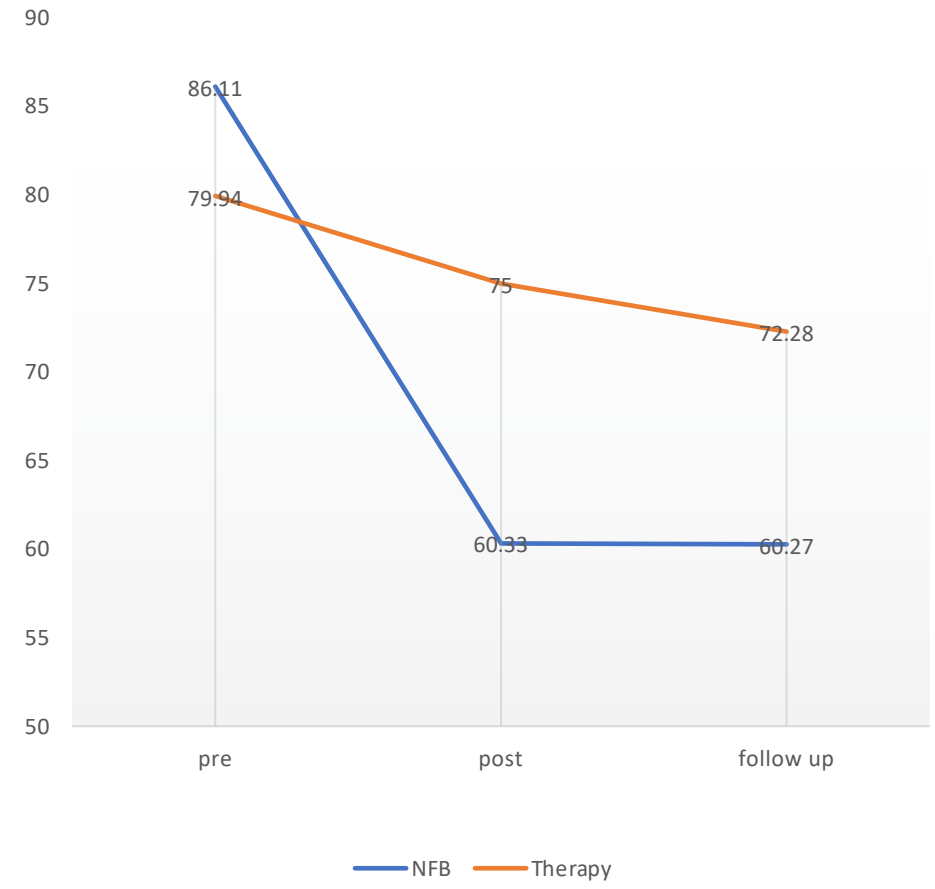
Depression Two Years Post Four Channel Multivariate Coherence Neurofeedback Treatment

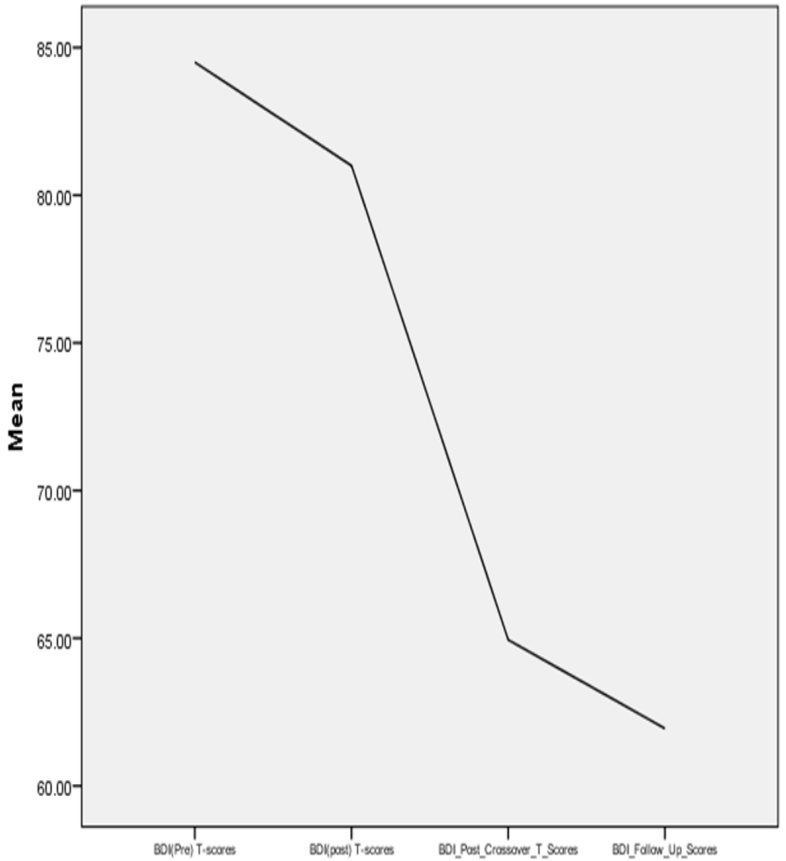
Abby Bolen, BA, BS, Caitlinn Mosley, BA, Robert Coben, PhD.

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


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

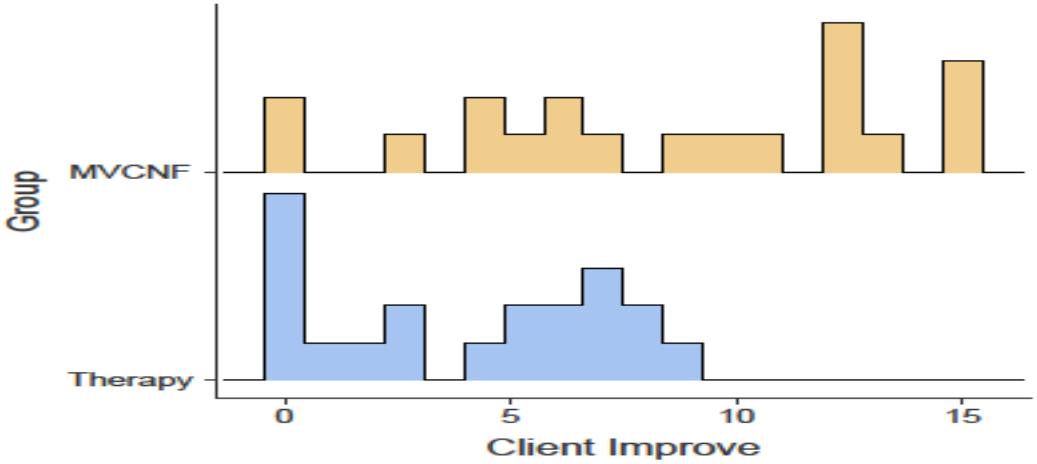
MVCNF for Developmental Trauma: Study Methodology

- Subjects were assigned to one of two groups (N = 40). Age range 10 – 65.
- These included an experimental group that received the active treatment (four channel multivariate coherence neurofeedback (20),and an alternate treatment comparison group (N = 20) that received individual psychotherapy. All subjects had experienced significant developmental trauma.
- All subjects in the experimental groups received four channel multivariate coherence training over 12-15 sessions.
- Clinical ratings and therapist ratings (0-20) were derived at the completion of their treatment regimen.
- Client ratings were largely subjective and based on self-ratings only or parental ratings at the completion of training and during the process.
- Therapist ratings were performed at the completion of training and were based on objective test findings including neuropsychological, behavioral and qeeg findings that reflected change over time.
- We also tracked the presence of negative symptoms, their severity and resolution during the training/treatment periods.
- QEEG analysis of change included measures of power at the component level, dipole sources, spectral properties, and multiple measures of graph theory connectivity.

ANOVA

ANOVA

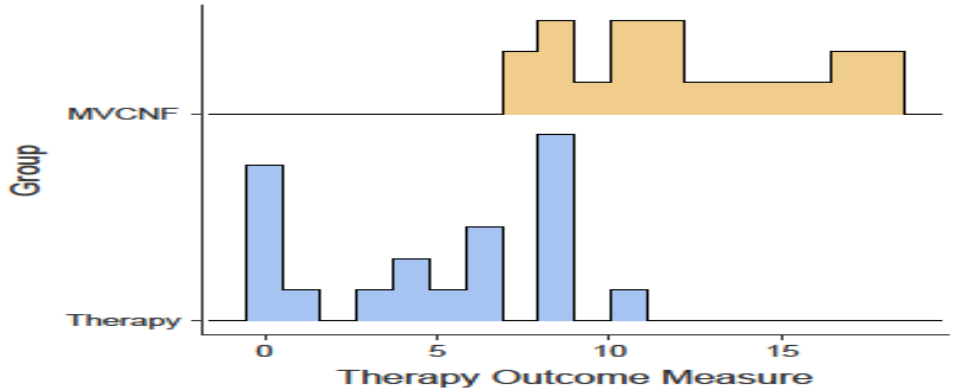
	Sum of Squares	df	Mean Square	F	p
Group	202	1	202.5	12.1	0.001
Residuals	636	38	16.7		



ANOVA

ANOVA

	Sum of Squares	df	Mean Square	F	p
Group	578	1	577.6	45.1	< .001
Residuals	486	38	12.8		



Graph Theory Connectivity Findings

Paired Samples T-Test

			statistic	df	p
Clust Coeff 2	Clust Coeff 1	Student's t	0.827	19.0	0.419
Path Length 2	Path Length 1	Student's t	-3.231	19.0	0.004
Global Eff 2	Global Eff 1	Student's t	2.470	19.0	0.023
Radius 2	Radius 1	Student's t	-2.472	19.0	0.023
Diameter 2	Diameter 1	Student's t	-3.618	19.0	0.002

Conclusions

- MVCNF leads to enhanced client and therapist ratings of outcome and to a greater degree than traditional psychotherapy.

- Client and therapist outcome ratings correlate but disagree with therapist ratings being higher (more accurate?).

- Mild, negative symptoms are possible but often can be resolved. These do not differ from psychotherapy and are often related to medication usage.

- Positive response to MVCNF in DT leads to decreases in delta, theta and beta activity over left temporal, precuneus (midline parietal), and right parietal brain regions. There were also increases in alpha and high beta over midline frontal (anterior cingulate) and right parietal-temporal regions.

- Positive responses are also seen with increases in multivariate connectivity, especially long range connectivity.

Meta-Analysis Procedure

Study Label	Sample Size
General Population (Multiple Diagnoses)	87
TBI	20
Epilepsy	26
Learning Disability	31
ASD General	55
ASD Mu Suppression	39
Depression	27
Developmental Trauma	20

Total N = 305

Group 1

Mean (*M*):

Standard deviation (*s*):

Sample size (*n*):

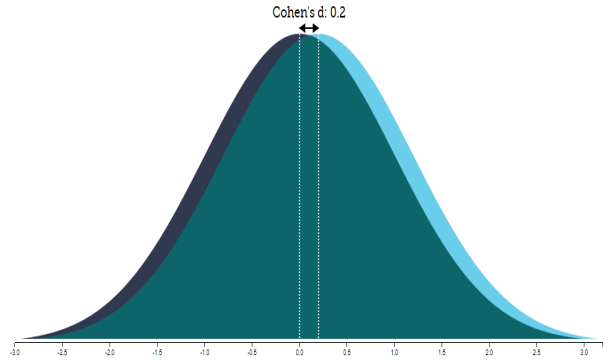
Group 2

Mean (*M*):

Standard deviation (*s*):

Sample size (*n*):

Calculate



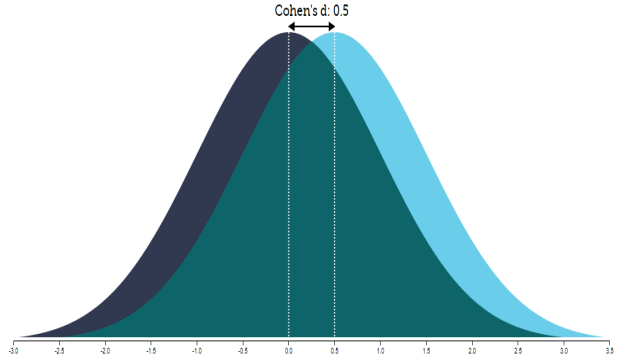
Interpretation

57.93 % Cohen's U_3

92.03 % % Overlap

55.62 % Probability of Superiority

16.51 Number Needed to Treat[1]



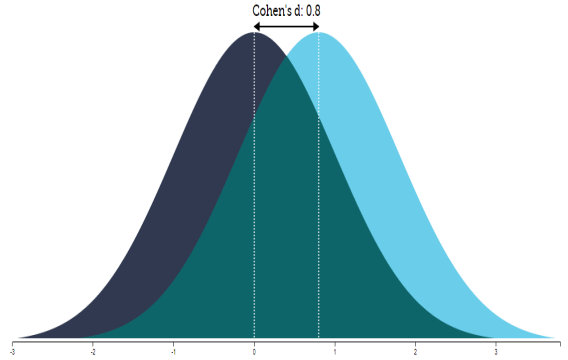
Interpretation

69.15 % Cohen's U_3

80.26 % % Overlap

63.82 % Probability of Superiority

6.01 Number Needed to Treat[1]



Interpretation

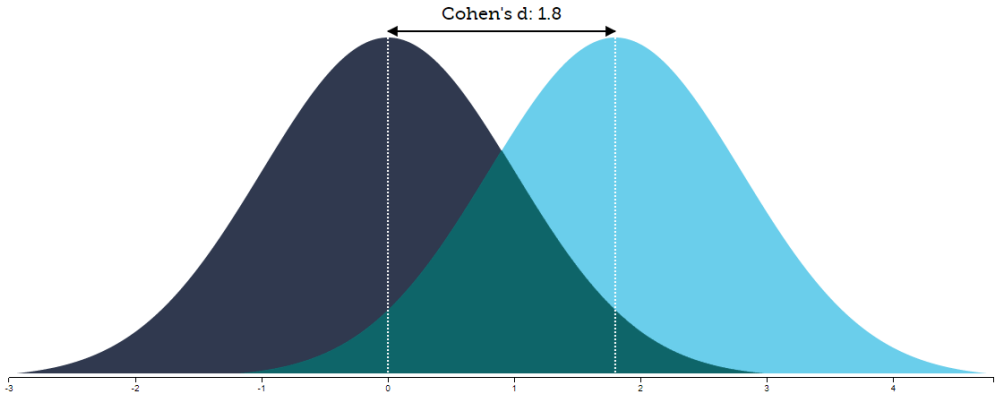
78.81 % Cohen's U_3

68.92 % % Overlap

71.42 % Probability of Superiority

3.53 Number Needed to Treat[1]

Clinical Effects



Interpretation

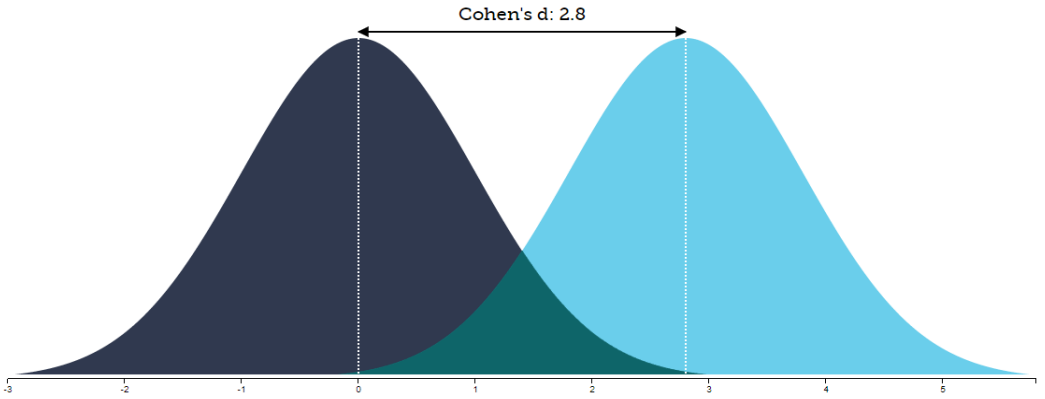
96.41 %
Cohen's U_3

36.81 %
% Overlap

89.85 %
Probability of Superiority

1.58
Number Needed to Treat[1]

Connectivity



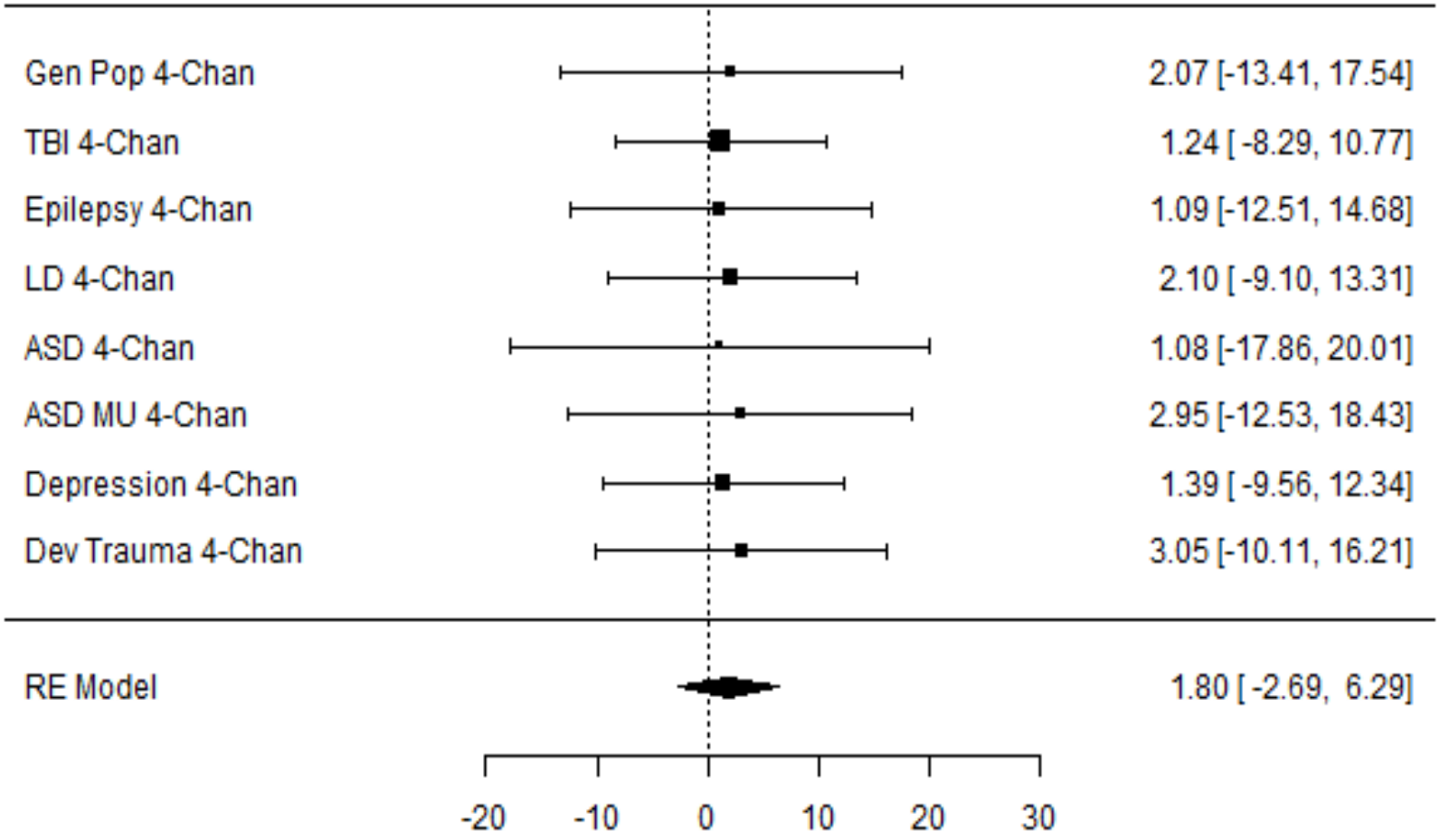
Interpretation

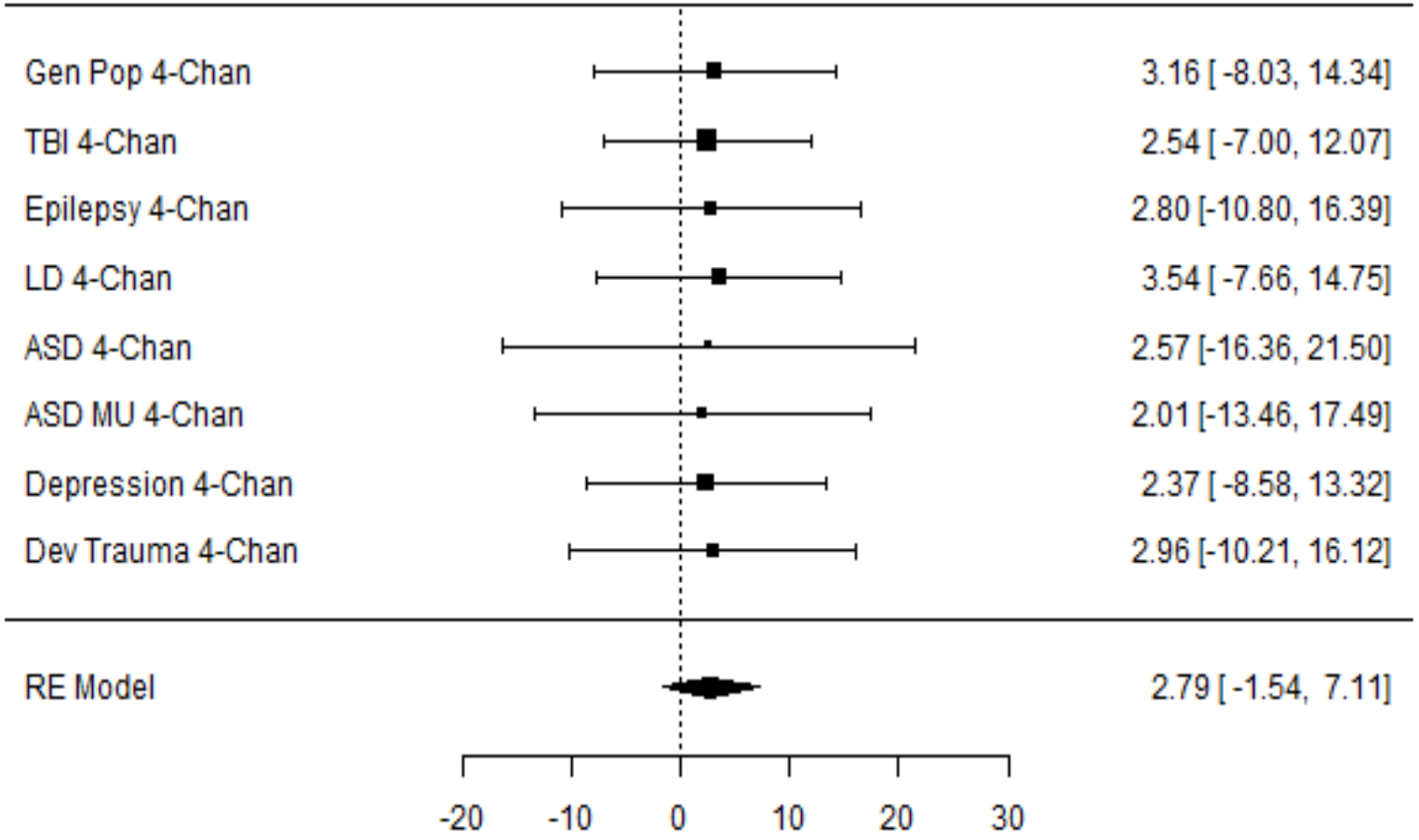
99.74 %
Cohen's U_3

16.15 %
% Overlap

97.61 %
Probability of Superiority

1.29
Number Needed to Treat[1]


Gen Pop 4-Chan
2.07 [-13.41, 17.54]
TBI 4-Chan
1.24 [-8.29, 10.77]
Epilepsy 4-Chan
1.09 [-12.51, 14.68]
LD 4-Chan
2.10 [-9.10, 13.31]
ASD 4-Chan
1.08 [-17.86, 20.01]
ASD MU 4-Chan
2.95 [-12.53, 18.43]
Depression 4-Chan
1.39 [-9.56, 12.34]
Dev Trauma 4-Chan
3.05 [-10.11, 16.21]
RE Model
1.80 [-2.69, 6.29]
-20
-10
0
10
20
30


Gen Pop 4-Chan
3.16 [-8.03, 14.34]
TBI 4-Chan
2.54 [-7.00, 12.07]
Epilepsy 4-Chan
2.80 [-10.80, 16.39]
LD 4-Chan
3.54 [-7.66, 14.75]
ASD 4-Chan
2.57 [-16.36, 21.50]
ASD MU 4-Chan
2.01 [-13.46, 17.49]
Depression 4-Chan
2.37 [-8.58, 13.32]
Dev Trauma 4-Chan
2.96 [-10.21, 16.12]
RE Model
2.79 [-1.54, 7.11]
-20
-10
0
10
20
30

Efficacy of Neurofeedback Treatment in ADHD: the Effects on Inattention, Impulsivity and Hyperactivity: a Meta-Analysis

Martijn Arns, Sabine de Ridder, Ute Strehl, Marinus Breteler and Anton Coenen

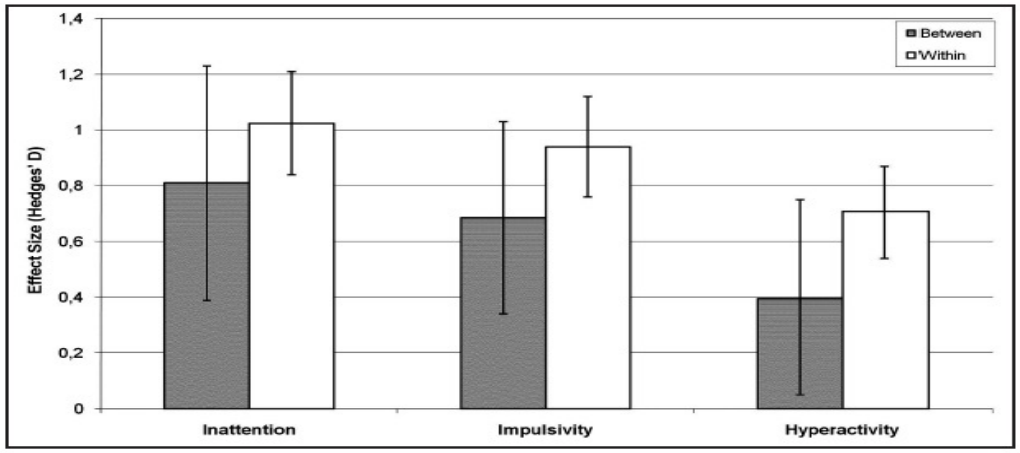
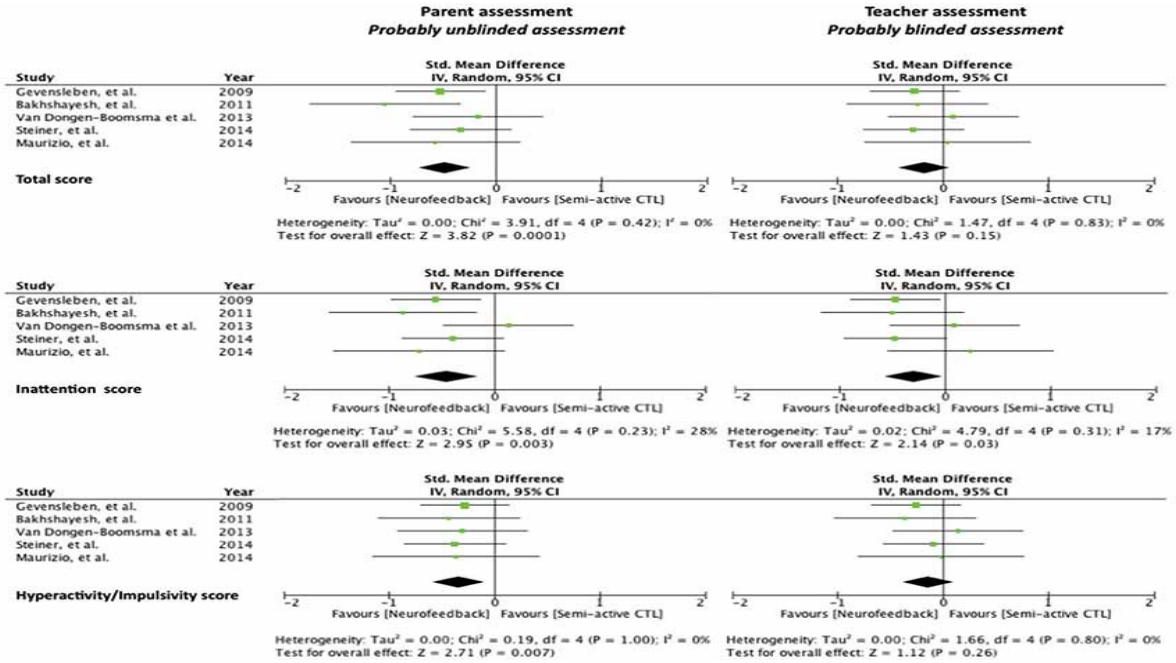


Figure 3.
This figure shows the grand mean ES for the controlled studies compared to the within-subject effect sizes for all studies for all 3 core symptoms. Note that the ES for the controlled studies are slightly smaller, which could be due to the fact that many controlled studies used a "semi-active" control group. Furthermore, given the 95% confidence intervals the ES for inattention, hyperactivity and impulsivity are significant for both comparisons.

Front. Hum. Neurosci., 13 November 2014 | https://doi.org/10.3389/fnhum.2014.00906

EEG neurofeedback treatments in children with ADHD: an updated meta-analysis of randomized controlled trials

Jean-Arthur Micoulaud-Franchi[1,2*], Pierre Alexis Geoffroy[3,4,5,6], Guillaume Fond[6,7], Régis Lopez[8,9], Stéphanie Bioulac[10,11] and Pierre Philip[11]



Using Effective Connectivity in Guiding NF: Study Methodology

- Subjects were assigned to one of three groups (N = 45). Age ranges 10 – 70.
- These included an effective connectivity (15), functional connectivity within group (15) and a functional connectivity between group (15) comparison. Group 1 and 2 were the same subjects (within groups) that received different interventions at different time points (FC always first).
- All subjects received four channel multivariate coherence training over 12-15 sessions.
- Clinical ratings and therapist ratings (0-20) were derived at the completion of their treatment regimen.
- Client ratings were largely subjective and based on self-ratings only or parental ratings at the completion of training and during the process.
- Therapist ratings were performed at the completion of training and were based on objective test findings including neuropsychological, behavioral and qeeg findings that reflected change over time.
- QEEG analysis of change included measures of power at the component level, dipole sources, spectral properties, and multiple measures of graph theory connectivity.

ANOVA

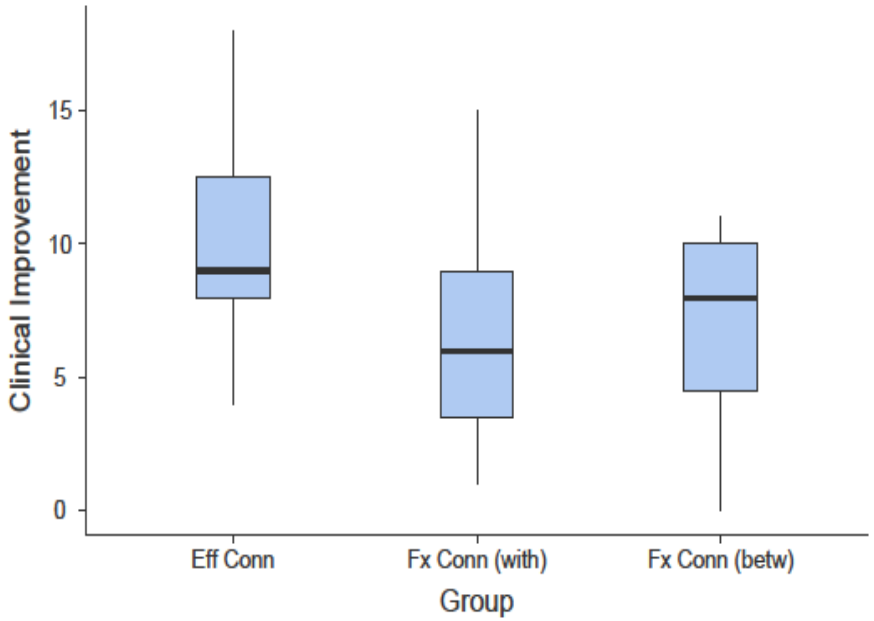
ANOVA

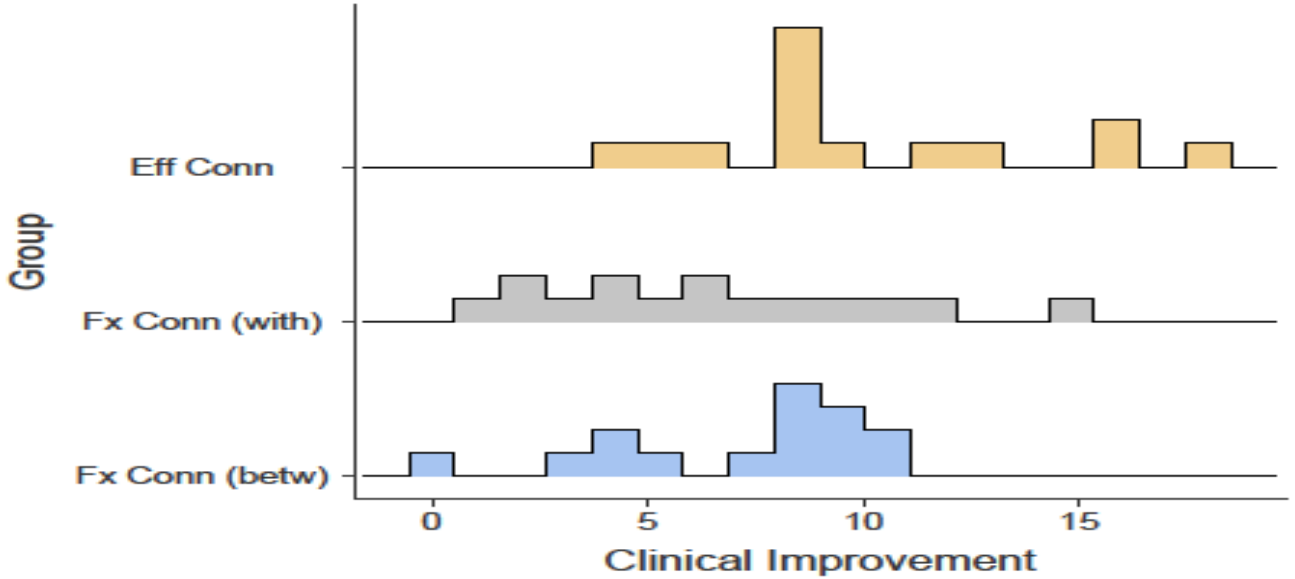
	Sum of Squares	df	Mean Square	F	p
Group	110	2	55.1	3.66	0.034
Residuals	631	42	15.0		

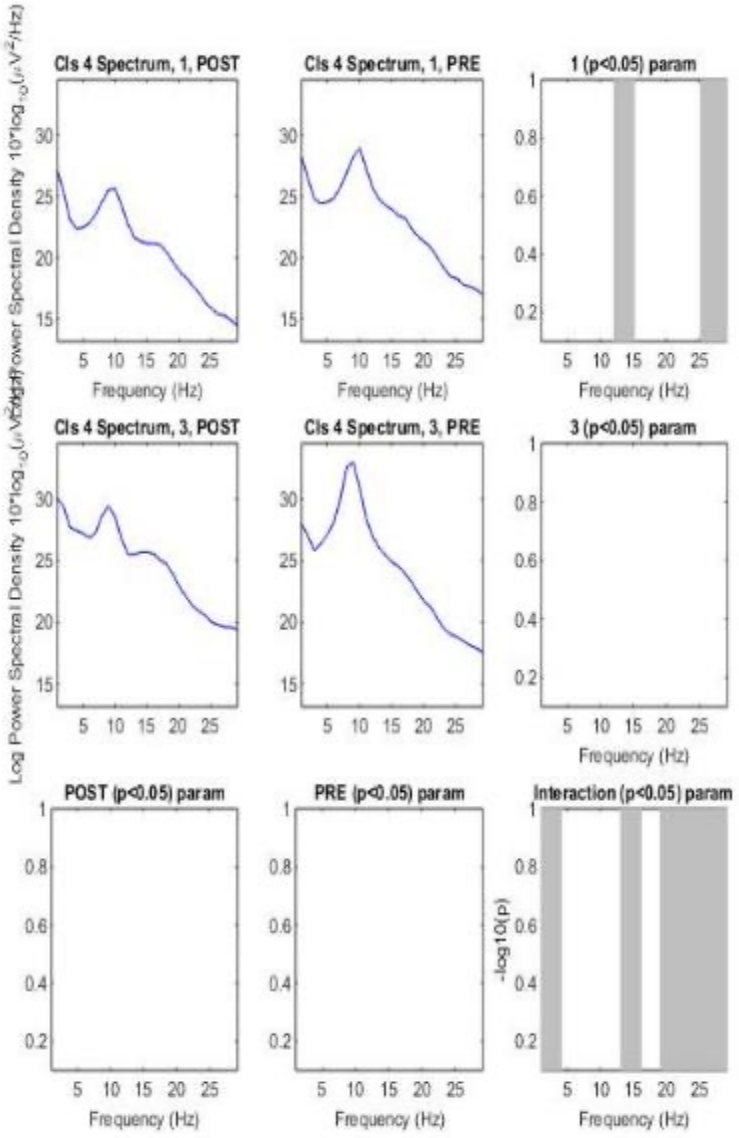
Contrasts

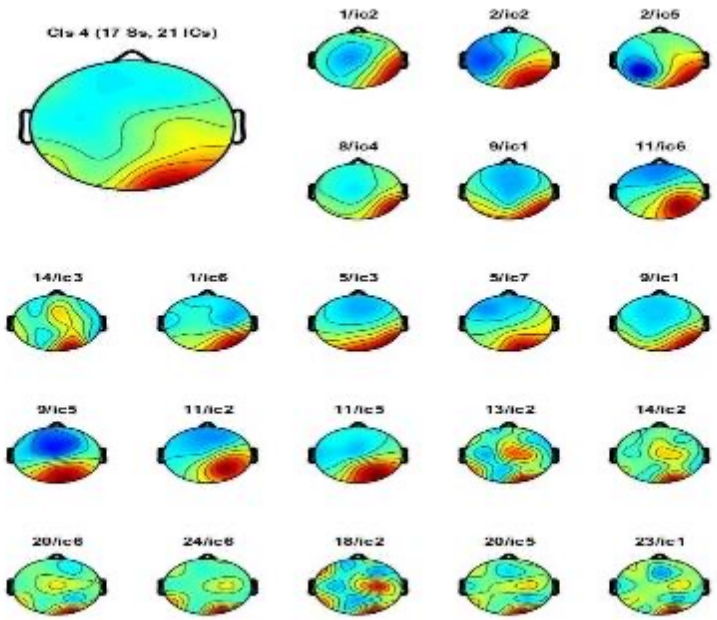
Contrasts - Group

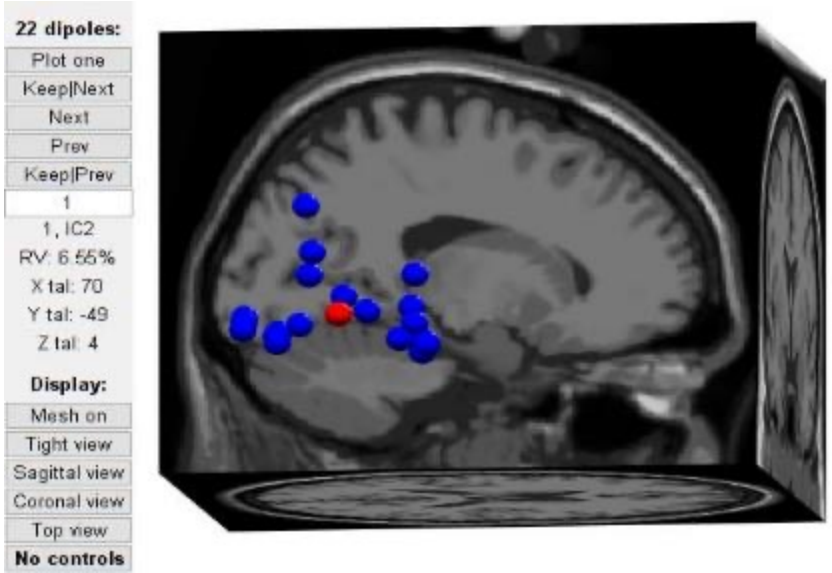
	Estimate	SE	t	p
Fx Conn (with) - Eff Conn	-3.67	1.42	-2.59	0.013
Fx Conn (betw) - Eff Conn	-2.80	1.42	-1.98	0.055






Cls 4 Spectrum, 1, POST
Cls 4 Spectrum, 1, PRE
1 (p<0.05) param
Cls 4 Spectrum, 3, POST
Cls 4 Spectrum, 3, PRE
3 (p<0.05) param
POST (p<0.05) param
PRE (p<0.05) param
Interaction (p<0.05) param
Log Power Spectral Density 10*log10(μV²/Hz)
-log10(p)
Frequency (Hz)

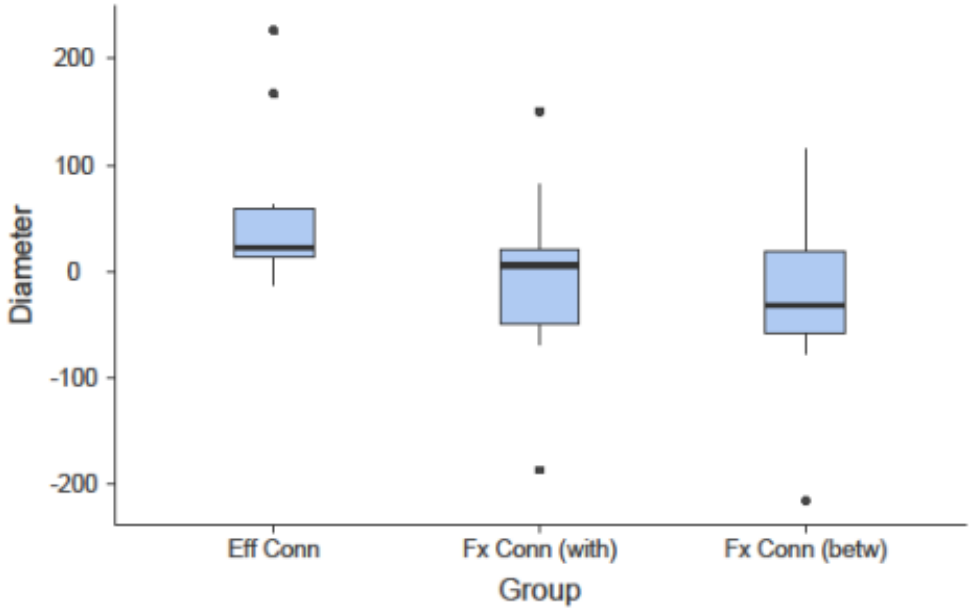

Cls 4 (17 Ss, 21 ICs)
1/ic2
2/ic2
2/ic6
8/ic4
9/ic1
11/ic6
14/ic3
1/ic6
5/ic3
5/ic7
9/ic1
9/ic5
11/ic2
11/ic5
13/ic2
14/ic2
20/ic6
24/ic6
18/ic2
20/ic5
23/ic1

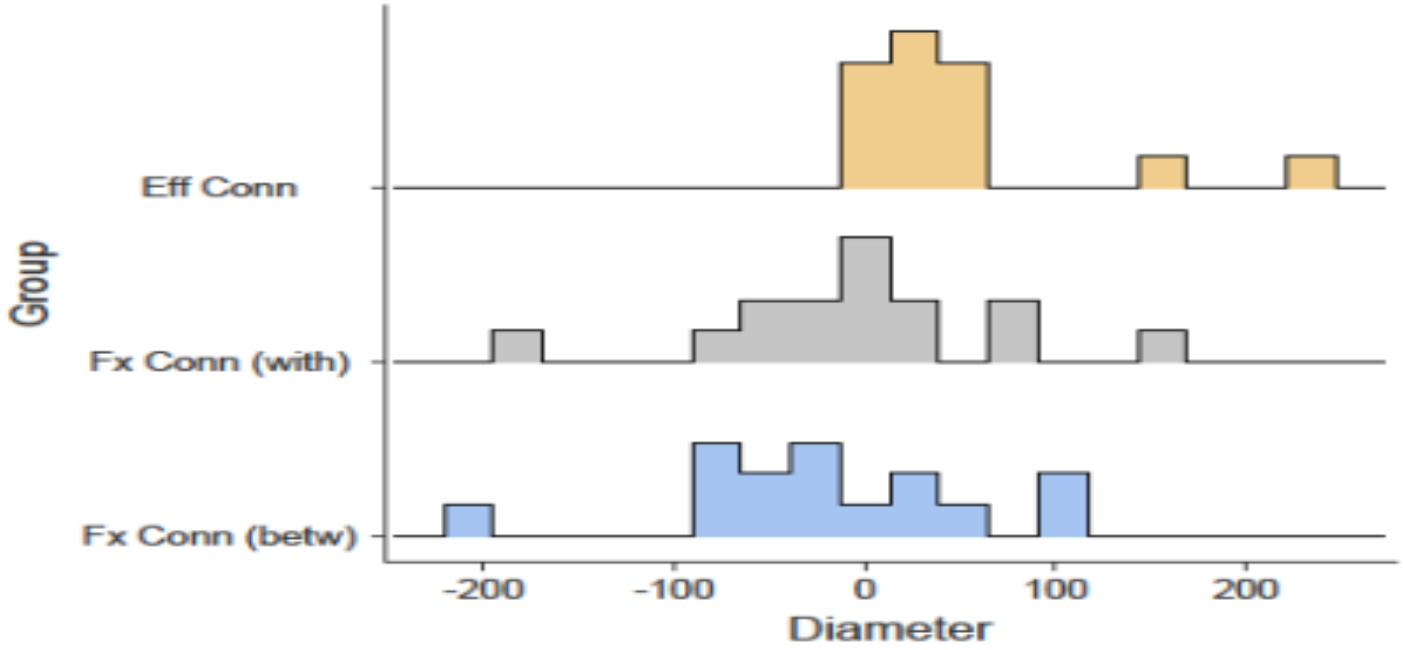

22 dipoles:
Plot one
Keep|Next
Next
Prev
Keep|Prev
1
1, IC2
RV: 6.55%
X tal: 70
Y tal: -49
Z tal: 4
Display:
Mesh on
Tight view
Sagittal view
Coronal view
Top view
No controls

Statistical Analyses of Graph Theory Metrics (Connectivity)

Analysis of Variance

Cluster Coefficient	Global Efficiency	Path Length	Radius	Diameter
F = 0.429	F = 4.60	F = 2.93	F = 3.35	F = 3.70
p = 0.654	p = 0.016	p = 0.064	p = 0.045	p = 0.033


200
100
0
-100
-200
Diameter
Eff Conn
Fx Conn (with)
Fx Conn (betw)
Group


Group
Eff Conn
Fx Conn (with)
Fx Conn (betw)
-200
-100
0
100
200
Diameter

Correlation Matrix

		Medications	Clinical Improvement	Therapist Outcome Measure	Diameter
Medications	Pearson's r	—	-0.142	-0.142	-0.027
	p-value	—	0.353	0.351	0.862
Clinical Improvement	Pearson's r		—	0.563	0.319
	p-value		—	< .001	0.033
Therapist Outcome Measure	Pearson's r			—	0.242
	p-value			—	0.109
Diameter	Pearson's r				—
	p-value				—

Conclusions

- Measures of effective connectivity can be gleaned from QEEG data.
- Effective connectivity guided multivariate coherence training led to enhanced client and therapist ratings of outcome.
- Therapist ratings are consistently higher than clients and show more significant differences.
- Both ratings show an increased likelihood of greater outcomes (> 10) in the effective connectivity group.
- Positive NF outcomes in this group showed greater reductions of delta/theta, alpha and beta frequencies. These were commonly seen over bilateral posterior brain regions including temporal locations and midline frontal locations as well.
- Positive NF outcomes were associated with greater changes in multivariate connectivity. This is especially true for long range connectivity (diameter).
- Use of effective connectivity leads to changes in connectivity and is more likely to prevent negative connectivity changes.

What have we learned?

- Coherence training is a helpful form on neurofeedback for many different types of problems.
- Problems with connectivity-based problems (i.e., autism, ld, depression, trauma) appear to benefit the most.
- Four channel multivariate coherence training appears more potent that two channel coherence training for multiple problems.
- This can be used to help many different disorders and has a persistent effect.
- The method used to calculate coherence/connectivity has a large impact on the efficacy of such interventions.
- Measures of effective connectivity enhance the efficacy of four channel multivariate coherence training.
- So much more to learn……

Thank you and to our team!

https://www.integratebrainhealth.com/

INS INPS HEADON!

INTEGRATED HEALTH COACHING IBN

INTEGRATE BRAIN HEALTH

Phone: 479-225-3223

Phone: 866-936-1882

email: admin@integrated-neuro.com

Mail to: 92 W. Sunbridge Drive Fayetteville AR