Neurofeedback Applications in Autism
Overview, Treatment Effects & Status of Research

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Terms: EEG Biofeedback (brainwave biofeedback)
Also called Neurofeedback
Neurotherapy
Neuroscience Basis of Neurofeedback

- Over 10,000 neuroimaging studies (MRI, fMRI, PET, EEG, qEEG) form the scientific basis of neurofeedback.

- The scientific literature includes decades of studies identifying EEG brainwave patterns associated with specific symptoms and disorders: neuromarkers. (DSM V to include neuromarkers for various diagnostic categories)

- Neuroscience advances have highlighted the importance of the understanding and addressing the neurobiological bases of mental disorders.

- Impaired brain development or brain injury leads to abnormal neuroelectrical and neurochemical patterns in the brain, and these in turn are associated with specific cognitive, emotional and behavioral symptoms that are actually transdiagnostic (common to many different disorders), rendering a specific diagnosis less relevant to treatments such as neurofeedback.

- The existence of research-identified EEG abnormalities for specific disorders provides a scientific rationale for treatment of these disorders with forms of neurotherapy.

- ASD is one of many disorders resulting from abnormal neurological development that has been found to have distinguishing EEG features (Duffy et al., 2012).
**First, Some Basic EEG Terms:**

### EEG Frequency Bands & Associated Subjective States

<table>
<thead>
<tr>
<th>Frequency Band</th>
<th>Measurement In Hz/cps</th>
<th>Corresponding State of Consciousness</th>
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<tbody>
<tr>
<td>Lo Beta</td>
<td>13-15 Hz</td>
<td>Relaxed but alert, Alert, outward focus of mental concentration</td>
</tr>
<tr>
<td>Beta</td>
<td>16-20 Hz</td>
<td>Anxious, ruminative, poor focus/attention</td>
</tr>
<tr>
<td>Hi Beta</td>
<td>21-30 Hz</td>
<td></td>
</tr>
<tr>
<td>Alpha</td>
<td>8-12 Hz</td>
<td>Relaxed, disengaged and calm, idling state: Internal mental activity driven by mental imagery</td>
</tr>
<tr>
<td>Theta</td>
<td>4-8 Hz</td>
<td>Detached semi-conscious, relaxed state associated w/ liminal states accompanied by hypnagogic (leading to sleep) and hypnopompic (waking from sleep) imagery</td>
</tr>
<tr>
<td>Delta</td>
<td>1-3 Hz</td>
<td>Sleep</td>
</tr>
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</table>
Neurometric Classification of Psychiatric Disorders

- Norm ($n = 60$)
- Uni Dep ($n = 69$)
- Bi-P Dep ($n = 35$)
- Alc ($n = 30$)
- Schiz ($n = 20$)
- MCI ($n = 76$)
- Dem ($n = 93$)

E. R. John, New York University NXLink database
Neurofeedback can be applied to:

- Disorders having a significant cognitive, emotional, neurological/neurodevelopmental component and disorders having a strong CNS arousal (over- or under-arousal) component.

- Examples of disorders of CNS **under-arousal**: ADD, ADHD, Depression
  Have excessive “slow wave” (0 – 14 Hz) EEG patterns

- Examples of disorders of CNS **over-arousal**: Anxiety, PTSD, OCD, Alcoholism, Anxiety Disorder, DTD/RAD
  Have excessive “fast wave” (>20 Hz) patterns

- Many disorders have both over- and under-arousal features (**instability patterns**): TBI, Bipolar, polysubstance abuse, plus many of above disorders
Disorders of cognition, communication and learning also involve lack of adequate connectivity (phase/coherence) between sites in brain that need to “talk” to each other in order to perform cognitive tasks such as reading, math, social communication.

Examples: Autism Spectrum Disorders, Head Injury. Dyslexia & other Learning Disabilities
Can we really control our brainwaves?

- The exact physiological mechanisms and foundations of this process are not yet fully understood, but repetitive practice of specific EEG responses, with feedback has been shown to reliably produce EEG changes in targeted directions.

- The ability of humans and animals to directly modify their scalp recorded EEG through feedback is a well established fact.*

What happens in EEG biofeedback?

- The biofeedback equipment records, amplifies, and “feeds back” to an individual what is happening with the electrical activity produced by clusters of nerve cells (neurons) in their brain.

- The EEG information is collected by small sensors attached to the scalp with an electrical conducting paste and two ear clips to form a recording circuit.
EEG Biofeedback/Neurofeedback Training

- During neurofeedback training, selected information on the individual’s brainwave activity is presented via computer in visual and auditory forms that can be easily understood, such as a simple line or bar graph or more engaging images/sounds, cartoons, video games, movies.
Neurofeedback is operant conditioning of brain and central nervous system activity

- NF training follows operant conditioning learning principles, in which the individual receives rewarding visual/auditory feedback when a targeted aspect of their brainwave activity reaches or is maintained at a desired level of *amplitude* (power or height of the brainwave) or *connectivity/coherence* between two brain locations.

- Learning trials (neurofeedback training sessions) are conducted at least twice a week over a period of several months (usually a minimum of 40 sessions with common disorders such as ADHD) as the brainwave activity is shaped gradually toward more normal levels.

- "Aerobics for the Brain", "Regulatory Challenge Model": gradually train brain away from dysregulated state into more normal regulation pattern

- More severe conditions require more sessions.

- As the brainwave patterns normalize, reductions will be seen in symptoms associated with the brain sites being treated.

- Response to other interventions tends to improve as the individual’s brain begins to function better. Meds can be reduced or eliminated.
How is a neurofeedback training plan developed?

The specific components of the brain electrical activity that are targeted for treatment and their location on the head are selected after symptom and EEG assessment (qEEG or brain map) and application of EEG research findings on brain abnormalities (neuromarkers) found to be associated with specific disorders, such as Autism.

Brain Map (qEEG)
Brain Map of 12 y.o. Girl with Moderate ASD

**Excessive slow waves:**
- front to back on vertex
- lack of frontal lobe dev.
- attention/concentration problems
- poor impulse control
- obsess.-compuls. behavior
- right frontal
- emotional reactivity
- right temporal
- poor recog. facial/social cues

**Excessive fast waves:**
- high anxiety

**Mu pattern on motor strip:**
- lack of frontal lobe control
- imitation/social deficits

**Abnormal Coherence patterns**
- lack of connectivity between lobes (not shown here)
- lack of normal brain development
- learning & communication probs.
How are neurofeedback treatment protocols selected and used?

Cortical areas found to have “abnormal” activity (excessive or deficient EEG activity as compared to an age-matched normal database) and that coincides with the individual’s symptoms, may be targeted.

Examples related to treating EEG abnormalities seen in ASD:

- An individual with excessive slow activity (e.g., theta or delta) in the frontal lobes (associated with poor attention, concentration, and impulse control) will be rewarded in training sessions for decreasing the amount of electrical activity in the slow brainwave frequency bands and for increasing activity in the more alert, cognitive (beta) range.

- Excessive fast and/or slow EEG activity down the middle of the head is associated with obsessive/compulsive behaviors and anxiety. Reduce fast & slow while increasing activity associated with relaxation and CNS quieting.

- Reduce excessive slow wave activity in the right temporal area (associated with poor recognition of facial expressions and social interaction skills).

- Correct excessive or deficient connections between brain areas

- Reduce excessive activity in parietal (sensory-motor area) associated with sensory integration problems.
How is a neurofeedback session conducted?

Trainee's screen would look like this.

Example shown here: “Thermometers” bar graph screen

Training objective: Keep each thermometer above or below the **threshold** mark.
Neurofeedback has been shown in various studies and clinical reports to reduce such symptoms as:

- Attention/concentration problems
- Poor impulse control
- Executive function, planning, judgment
- Social anxiety; interpersonal communication; eye contact and demonstration of affection
- Emotional reactivity and “melt downs”
- Sensory integration problems
- Learning disabilities
- Speech and language difficulties
- Obsessive behaviors and speech, tics, “stimming”
Case Example
with Pre-Post Assessments

Childhood Disintegrative Disorder (CDD)/Autism

Treated by doctoral interns at UNT Neurotherapy Lab
2006 - 2007
Background History

- 12 year old girl
- Has a twin brother, *in vitro* fertilization
- C-section, normal birth
- Very social and bright, tested in pre-K
- Normal development milestones until age 4.9
4.9 years, received vaccinations (5/99) at the same time as received tetanus shot and recovering from an illness

- “quirky” changes for a few months (e.g. disorientation)
- Sudden, dramatic onset at 5th b-day party (8/99): panic, crying, stiffening, hallucinations of ghosts, inconsolable
- “Breakdowns” at pre-school, seizures, “terrifying rages”
- Total loss of language (echolalia), loss of drawing skills
Health History

- Age 5-8 years (‘99-02) parents describe her as “not with us”:
  - Manic jumping over furniture (3 days w/o sleep)
  - Screaming, arching, frantic crying w/o reprieve
  - Inability to communicate, little eye contact
  - Thyroid disorder - Goiter
  - Facial tic/left side contortion
  - Attention span < 10 sec
Health History cont.

- No family history of ASD or seizure disorder

- 6 day video EEG at Cook Children’s (1999)
  - Neurologist diagnosed - “constant seizure disorder”
  - Tried numerous anti-convulsivant meds, none effective

- Admitted to Psychiatric Ward 4 times; the last time she stayed for 2.5 months (2002).

- Family frustrated over treatment as a psychiatric, rather than a neurologic disorder
2003-2005, Psychiatrist at Washington University prescribed a Ketogenic diet (high fat, low carb)
- “Extremely beneficial”
- Mom reported at age 9, daughter “finally looked at me”

Until spring 2007 on a modified Atkins-type diet
- Artificial sweeteners and allergies exacerbate symptoms
Chief Concerns

- When entered Neurotherapy Program, she presented like a child on the autism spectrum

- Diagnosis: Childhood Disintegrative Disorder (CDD):
  - Minimal eye contact, closed body movements, limited reciprocal conversation, repetitive language, poor attention, anxious/upset by change, low threshold for stimuli
  - Seizures 1-2x/wk (crying, stiffening)
  - Low frustration tolerance (cursing, yelling)
Chief Concerns cont.

- Academically: 1st-2nd grade; tutoring and resource room; recently reading
  - Receiving Occupational and Speech Therapy
- Poor personal hygiene
- No modesty
- No friends
- Occasional eye contact
- Did not show affection
Assessment Instruments

Quantitative EEG (qEEG)

Amen Behavior Checklist
(based on work of Daniel Amen correlating brain areas involved with symptoms)

TOVA (continuous performance test)

Child Behavior Checklist

Symptom and function reports
Neurofeedback Treatment

- Mother drove over 100 miles round trip to Denton 2 x per week for approximately 1 year for daughter’s treatment. (Mom received biofeedback for stress while daughter in sessions too)
- Over 100 sessions conducted over course of year, with a couple of breaks after 40 session treatment rounds
- Protocols based on qEEG results, CBCL, and symptom reports (TOVA invalid: child unable to perform test)
- Treated all sites shown to be abnormal in qEEG and associated with reported symptoms
- Child continued most treatments/diets previously receiving
Pre & Post Treatment QEEG Assessments

Pre Treatment 2006

Post Treatment 2007
AMEN Behavior Checklist Results

Pre

Post

Amen Behavior Chart

Score

Deep Limbic

Pre-frontal Cortex

Cingulate System

Temporal Lobe

Basal Ganglia

Pre-frontal Cortex

Cingulate System

Temporal Lobe

Basal Ganglia
## Summary of Gains Pre-to-Post-Treatment

<table>
<thead>
<tr>
<th>Pre</th>
<th>Post</th>
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<tbody>
<tr>
<td>Low tolerance of frustration</td>
<td>Better control of herself</td>
</tr>
<tr>
<td>Lack of modesty</td>
<td>Modesty</td>
</tr>
<tr>
<td>Poor eye contact</td>
<td>Great eye contact</td>
</tr>
<tr>
<td>No affection</td>
<td>Shows affection</td>
</tr>
<tr>
<td>Academically: 1\textsuperscript{st} – 2\textsuperscript{nd} grade</td>
<td>Academically: 4\textsuperscript{th} - 6\textsuperscript{th} grade</td>
</tr>
</tbody>
</table>
At 1-year + Follow-up

Mother reported continued improvement in function:

- Maintained and built on mid- and post-treatment gains
- Mainstreamed & progressing well at school
- Has friends
Other cases currently in treatment locally:

- **10 y.o. boy with agenesis of corpus collosum/Autism**
  almost no speech, poor social communication, short attention span, etc.
  Began making eye-contact; speaking in full sentences; completing tasks at home and school; better school performance, reduction of social anxiety
  Treatment continuing

- **8 y.o. girl diagnosed ASD**: 
  no speech, no affection, tactile sensitivity, anxious, melt downs, hyperactive
  Now speaking in short sentences, eye contact, increased attention span, fewer and shorter emotional spells, told mom, I love you.”
  Treatment continuing
Controlled Studies to Date on Neurofeedback for ASD

Recent review of Neurofeedback Studies for ASD*

Reviewed 5 controlled studies of varying quality; several case studies. The authors concluded:

- All studies reported significant symptom reductions and improvements in overall functioning, but no single NF training protocol used that can be recommended as most effective. (To be expected if qEEG-guided protocols)
- Neurofeedback has been shown to be as effective as stimulant medication
- More recent studies have improved designs with fewer limitations; but more studies recommended to continue clarifying effects of various protocols for various forms of ASD
- Authors concluded that neurofeedback can be recommended for ASD when ADHD involved, but further refinement and tweaking of research needed to ferret out which specific protocols work best for specific ASD subtypes

My assessment of status of NF research for ASD

- NF research suffers from the usual problems encountered in doing clinical research today: The time and expense of large clinical RCT studies; years to get studies from funding to publication; the difficulty finding sufficient numbers of subjects; ethical and practical considerations of using control conditions in clinical settings), the diminution of potential positive outcomes caused by restrictions on normal treatment methods because of demands of strict RCT designs.
- Repeated single case designs are more appropriate for this type of treatment paradigm (a learning rather than pharmacological model)
- All studies to date involved too few treatment sessions (up to 30), an insufficient number of learning trials). 40 sessions minimum is norm in clinical practice.
- More research needed to continue the trajectory of improvement in understanding of the EEG features of ASD, especially defining its neurological variations.
- Research to date warrants designation of NF for ASD as “Evidence Supported” (Bohart, 2005).
- “Evidence Based” for certain forms of ASD (when ADHD part of diagnostic picture).
Availability and cost of Neurofeedback

- There are over 50 BCIA certified Neurofeedback providers in Texas. (But get a recommendation from someone who has worked with a neurotherapist you are considering).

- Most insurance carriers will not pay for any form of biofeedback at present. A few M.D.’s are getting reimbursement by billing it as an “office visit”.

- Fees range from $65 to $150 per session; initial qEEG and other assessments can range from $300 – over $1000.

- Neurofeedback is not for everyone; multiple sessions per week over several months can be difficult for some, and consistency is essential to success.
For more information on Neurofeedback:

- www.isnr.org
- www.unt.edu/neurotherapy
- To contact me: genie@unt.edu