The enhancement of Neurofeedback with a low cost and easy-to-use NeuroSky EEG biofeedback training device: The MindReflector Protocols

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Purpose

To present information about the development, testing and recent clinical use of a simple, easy to use and inexpensive EEG Biofeedback system adapted from the NeuroSky MindWave headset.
Goals

- Discuss the product, history of development and current protocols
- Discuss limitations and advantages of the system
- Present data from proof of concept testing
- Summarize the results of Beta testing, including reports of benefit, ease of use and reactions to the device
- Present preliminary efficacy data with regard to attention training
- Discuss the usefulness of MindReflector to date in an active clinical practice
The appeal of home training

- Frequency of use extends the impact and efficacy of Neurofeedback
- Empowerment – control in the hands of the user
- Home training would be particularly appealing if inexpensive, easy-to-use and reliable
Historic impediments to Home-training

- Cost
- Convenience – paste, wires, set-up
- Control of the protocols
- Compliance
NeuroSky and the MindWave/MindWave Mobile headsets
Characteristics of the headset

- One dry sensor on a moveable bar that generally is placed at FP1/FPZ
- Ear clip for left ear
- Dry, Wireless connection
- Uses one AAA battery and is connected to computer by RF signals or Bluetooth
- Light, sturdy, and easily applied
Specifications

- Weighs 90g
- Sensor arm up: Height: 225mm x Width: 155mm x Depth: 92mm
- Sensor arm down: Height: 225mm x Width: 155mm x Depth: 165mm
- 30mW rate power; 50mW max power
- 2.420 - 2.471GHz RF frequency
- 6dBm RF max power
- 250kbit/s RF data rate
- 10m RF range
- 5% packet loss of bytes via wireless
- UART Baudrate: 57,600 Baud
- 1mV pk-pk EEG maximum signal input range
- 3Hz – 100Hz hardware filter range
- 12 bits ADC resolution
- 512Hz sampling rate
- 1Hz eSense calculation rate
EEG Data provided by MindWave

Monopolar Measurements of the EEG, producing:

- Raw digitized EEG signal
- EEG power spectrum (FFTs for EEG bandwidths from .5 to 50 Hz)
- eSense meter for Attention
- eSense meter for Meditation
- eSense Blink Detection
- Strength of connection indicator
Current Use of NeuroSky technology

- Games -- The Mattel Force Trainer and the MindFlex
- Attention trainers (using the NeuroSky eSense algorithms for attention)
- Relaxation Training (using NeuroSky eSense algorithm for relaxation)
- Brain-Computer Interface (BCI) technology
Our Interest

Using the platform of EEG bandwidths provided by the headset to produce true Neurofeedback, with augments and inhibits and auditory and visual feedback.
Issues

- What EEG bandwidth information is available?
- How reliable is the signal?
- Limitations
  -- Only one site – frontal (FPZ/FP1)
  -- FFT analysis, with problems that can be inherent in such an analysis
  -- FFT bands are approximations of commonly desirable bandwidths
  -- Rapid sampling rate (512/sec), with 1 sec. data packets
- Will it support Neurofeedback?
- Safety concerns – is home training with the device safe?
EEG Data provided by MindWave

Monopolar Measurements of the EEG, producing:

- Raw digitized EEG signal
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## MindWave FFT Analysis

<table>
<thead>
<tr>
<th>Name</th>
<th>Frequency range</th>
<th>Preferred range</th>
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<tbody>
<tr>
<td>Delta</td>
<td>0.5-2.75 Hz</td>
<td>0.5 – 3.0</td>
</tr>
<tr>
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<td>3.0 – 7.0 or 4.0 – 8.0</td>
</tr>
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</tr>
<tr>
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<td>10.0 – 12.0</td>
</tr>
<tr>
<td>Low Beta</td>
<td>13-16.75 Hz</td>
<td>SMR Low Beta</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.0 – 15.0</td>
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<tr>
<td></td>
<td></td>
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</tr>
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<td>High Beta/ Low Gamma</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23.0 - 38.0</td>
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<tr>
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<td>Mid Gamma</td>
</tr>
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Reliability of the signal

“The NeuroSky chip filters out the ambient waves present in most uncontrolled conditions and effectively measures neural activity in virtually any condition with 96% the accuracy of similarly configured research grade EEGs.”

Comparisons with the Biopac System
Reliability of the signal

Comparison with the Biopac System

Figure 3. Raw EEG signals of NeuroSky and Biopac systems 
(Red line is Biopac, blue line is NeuroSky)

Figure 6.1: Figure 3

The red line represents the raw EEG signal of the Biopac system, while the blue line represents the raw EEG signal of the NeuroSky system. Both systems show a similar wave pattern during the resting state, as well as sensitivity to eye blinks.
Clinical Use

- With proper instruction and application, the adjustable headset works well and supports Neurofeedback for most people
Monopolar Placement

- History of EEG Biofeedback started with one-site training
- Any perturbation of a site affects all other sites (E. Roy John)
- EEG communication occurs across hemispheres even without a corpus callosum
- If the site is not ideal, it is possible with a home unit to simply do more training
Feedback Timing

- NeuroSky on-board FFT and filters
- Sampling rate of 512 measurements/sec
- Information is delivered to the apparatus in one second packets

The brain is a time-sensitive organ – a flexible, synchronizing system that responds to the feedback with which it is presented.
The MindWave platform delivers close approximations of desirable bandwidths

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Can you do EEG Biofeedback with the MindWave platform?

This is an empirical question

Presenting supporting data from 9 months of MindReflector™ use
Is It Safe?
Overview and results to date on questions of safety

- Wide-spread use of the device for games, relaxation and attention training without noted difficulties
- MindReflector system is gentle and non-perturbing
- Feedback from Beta testers and other users has produced overwhelmingly positive effects
- In my 13 years of experience using multiple bandwidth FFT protocols, I have never observed excessive reactivity or any other negative effects form training.
MindReflector™ Development

- A Windows-based unit that works on XP, Vista and Windows 7
- Four inhibit-augment protocols using available bandwidths that closely match desirable protocols
- Auto-thresholding with our own bio-signal monitoring algorithm
- An adjustable difficulty bar
- Windows Media Player for audio/visual feedback
- Training screen and a control screen in a way that could be used for a home trainer or in the office with two screens
Training with the MindReflector System
MindReflector Protocols

Quiet Focus Training

**Inhibit:** Delta (0.5 – 2.75 Hz), Theta (3.5 - 6.75 Hz) and Low Gamma (31.0 – 39.75 Hz)

**Augment:** Low Beta (13.0 - 16.75 Hz)

Meditative Relaxation Training

**Inhibit:** Delta (.5 - 2.75 Hz), Theta (3.5 - 6.75 Hz), and Low Gamma (31.0 – 39.75 Hz)

**Augment:** Low Alpha (7.5 - 9.25 Hz) and High Alpha (10.0 - 11.75 Hz)
MindReflector Protocols

Full Spectrum Training

**Inhibit:** Delta (.5 - 2.75 Hz), Theta (3.5 - 6.75 Hz), Low Gamma (31.0 – 39.75 Hz)

**Augment:** Low Alpha (7.5 - 9.25 Hz), High Alpha (10.0 - 11.75 Hz), and Low Beta (13.0 – 16.75 Hz)

Alpha Theta Training

**Inhibit:** Delta (.5 – 2.75 Hz) and Low Gamma (31.0 – 39.75 Hz)

**Augment:** Theta (3.5 – 6.75 Hz) and Low Alpha (7.5 – 9.25 Hz)
MindReflector Control Screen
Training Options

- Training Screen
- Auditory Options

**Options**
- COM Port: AUTO
- Quiet Focus Training
- Meditative Relaxation
- Full Spectrum Training
- Alpha/Theta Training
- Enable Statistics

Currently Selected Media File: Endless_Fall_Tullio.mp3

[Images and graphs related to EEG brainwave profile and Neurofeedback Training]
Feedback Options

Training Screen is as customizable as is Windows Media Player. Users can add plug-ins and their own audio and video files.
Empirical Support

- Proof of concept testing
- Beta-tester feedback
- Efficacy of attention training
Does using the MindReflector™ alter a person’s EEG the way it is intended?

Will in-office training with MindReflector alter the amplitude of selected bandwidths in independent measures?
Eight Volunteer Subjects were trained for 15 – 20 minutes on the Quiet Focus and Meditative Relaxation MindReflector protocols while bilateral EEG measurements were being taken at C3/C4 with the BrainMaster system.
Results

Subjects responses and comments after training

- One subject initially found the task interesting, but later found the task boring. The remainder indicated they liked it, it was “cool,” and it was interesting.

- During attention training, five of the eight indicated they felt more focused. One instructive comment: “When I lost focus, it got me to focus again.” Three of the subjects also indicated they felt sleepy toward the end of training.

- After the relaxation training, all subjects indicated they felt more relaxed or even sleepy.
Attention Training

Augment: Low Beta (13 – 16.75 Hz)
Inhibit: Delta (.5 – 2.75), Theta (3.5 – 6.75), Low Gamma (31.0 – 39.75)

Comparison of overall mean amplitude values during the initial three minutes vs. final three minutes of training

Findings
Additional Data Analysis

Attention training (which straddled LoBeta and Beta)

First Half vs. Second half comparisons

Chi Square Analysis of expected vs. obtained frequencies

- Lowest LoBeta values in first half vs. second half
  12 vs. 4  Chi Square = 2.133 (p < .15)
- Lowest Beta in first vs. second half
  13 vs. 3  Chi Square = 3.463 (p = .06)
- Highest LoBeta in second half
  12 vs. 4  Chi Square = 2.133 (p < .15)
- Highest Beta in second half
  14 vs. 2  Chi Square = 5.236 (p < .05)
Relaxation Training

Augment: Low Alpha (7.7 – 9.25 Hz), High Alpha (10.0 – 11.75 Hz)
Inhibit: Low beta (13.0 – 16.75 Hz), Low Gamma (31.0 – 39.75 Hz)

Comparison of overall mean amplitude values during the initial three minutes vs. final three minutes of training

Findings
Beta Testing

How did subjects react to the use of the device and protocols?

Description of procedure
Summary of Responses to Training

- Quiet focus
- Meditative Relaxation
- Full Spectrum
- Alpha Theta
Efficacy testing: Will training with the attention protocol produce independently measurable improvements in attention skills?

Description of the study

Pre-post IVA-Plus testing

Three weeks of almost daily attention training

Results

Preliminary findings
What observations have I been able to make about the system’s clinical usefulness?

My experience in the office
Conclusions

1. MindReflector™ trains the brain/mind system as intended.

2. This training supports relaxation, attention and general brain states in a way that augments the treating professional.

3. Not a substitute for office-based practice, but a good augment.

4. Ability to use multiple times at home greatly increasing frequency of training and potential benefit.

5. It has clearly been beneficial in my practice. It has reported benefit for sleep enhancement, attention and focus, relaxation and reduction in perceived anxiety.

6. Development is underway, both in terms of supportive research and system performance.

7. It has been safe and easy to use by participants.
Future Directions

- Further in-office testing
- Additional controlled research
- New protocols
- New RAW EEG wave analyses
- Mac OS X version in development
- Mobile applications