

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

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Abstract: A wireless, dry, inexpensive and easy to use EEG home training device, adapted from the NeuroSky MindWave headset, will be presented, along with proof of concept data, Beta testing reactions and preliminary efficacy findings. Attention will be given to the development of the device and its use of four power-training protocols developed from the available NeuroSky bandwidth platform. Training and control screens will be illustrated. Finally, the benefits and limitations of the device will be discussed, with focus on its ease of use vs. the temporal, bandwidth and site restrictions of the training device.

Based on the content of this presentation, the participant will be able to....

1. Describe the NeuroSky MindWave headset, including its current availability for EEG games (e.g., The Force Trainer) and its underlying EEG bandwidth platform.
2. Understand the MindReflector adaptation of the MindWave headset, including the development of four potentially relevant training protocols.
3. Explain the potential benefits, as well as limitations, of the current MindReflector system.
4. Describe proof of concept data demonstrating the use of the MindReflector device to train changes in relevant bandwidth amplitudes.
5. Discuss responses and reactions during Beta testing with the four MindReflector protocols.
6. Outline the usefulness and limitations of home training for an active Neurofeedback practice.



MindReflector™ C-1 Model Neurofeedback Training Application

Product Description

The MindReflector C-1 Neurofeedback Training Application is a true EEG Biofeedback/Neurofeedback training device. It utilizes state-of-the-art technology to assess the user's state of mind and deliver information about these states in the form of auditory and visual signals. The MindReflector device uses this information to encourage desirable changes in the user's EEG signal.

The MindReflector C-1 application uses EEG brainwave data received from the NeuroSky MindWave headset. (For further information on NeuroSky brainwave technology, see www.neurosky.com.)

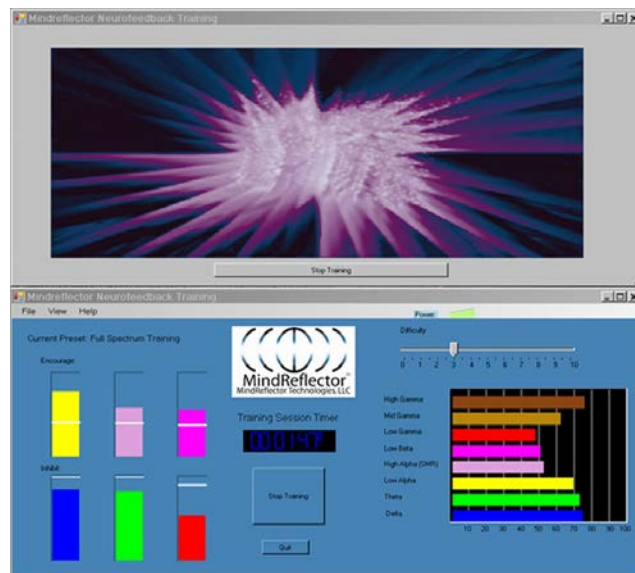
Real-time information about a user's state of mind is provided by the MindReflector application to offer four different training protocols: Quiet Focus, Meditative Relaxation, Full Spectrum Training, and Alpha/Theta Training. These protocols incorporate proprietary algorithms based on current brain-behavior research and knowledge of the neural correlates of consciousness.

The MindReflector C-1 interprets data received from the headset in the form of digital information about the amplitude of frequency ranges varying from .5 to 49.75 Hz. These ranges approximate eight important EEG signal bandwidths: Delta, Theta, Low Alpha, High Alpha (SMR), Low Beta, Low Gamma, Mid Gamma, and High Gamma.

The training protocols monitor the amplitudes of relevant groups of EEG bandwidths to operate a media playback stream. As determined by the MindReflector protocols, specific bandwidth amplitudes are augmented or encouraged to increase, while others are inhibited or encouraged to decrease.

During the operation of the device, feedback is delivered based on dynamically adjusted amplitude targets. While the adjustment of the targets is carried out automatically, protocol difficulty can be manually adjusted to individualize training sessions. Protocol choice and difficulty specification can be managed by the user or by a clinical operator. Application of the three methods of control, built-in algorithms, manual control, and dynamic automated adjustments, provides a wide range of training options for each protocol and within each session.

The operator/user selects a specific protocol from a drop-down menu. Additional options are then made available that include the selection of a statistics report and the choice of specific media file to be played during the session (audio with accompanying visualizations or a pre-recorded video). In addition to default media options, users may select a media file available on the user's computer or network. The MindReflector application alters whatever audio or video choices are made so that changes in a user's EEG are reflected in the operation of the media player.



Training Protocols for C-1 Model

Relaxed Focus training

Augment Low Beta (13.0 – 16.75 Hz)
Inhibit Delta (.5 – 2.75 Hz)
Inhibit Theta (3.5 – 6.75 Hz)
Inhibit Low Gamma (31.0 – 39.75 Hz)

Alpha-Theta Training (Eyes closed)

Augment Low Alpha (7.5 – 9.25 HZ)
Augment Theta (3.5 – 6.75)
Inhibit Delta (.5 – 2.75)
Inhibit Low Gamma (31 – 39.75 Hz)

Meditative relaxation Training (Eyes closed)

Augment Low Alpha (7.5 – 9.25)
Augment High Alpha/SMR (10.0 – 11.75)
Inhibit Low Beta (13.0 – 16.75)
Inhibit Low Gamma (31.0 – 39.75)

Full Spectrum Training

Augment Low Alpha (7.5 – 9.25)
Augment High Alpha (10.0 – 11.75)
Augment Low Beta (13.0 – 16.75)
Inhibit Delta (.5 – 2.75)
Inhibit Theta (3.5 – 6.75)
Inhibit Low Gamma (31.0 – 39.75)

Proof of Concept Study

Does training with the **MindReflector** produce changes in the EEG as concurrently and independently measured by a two-channel BrainMaster system?

Procedure

Seven subjects were involved in two consecutive 16-minute training sessions with MindReflector software using the Quiet Focus and Meditative Relaxation protocols. An additional subject took part only in the Quiet Focus training. Subjects were blind to the specific nature of the protocols that were used, which were randomly varied in order across subjects. During training, the subjects' EEG activity was independently measured at C3 and C4 with a BrainMaster EEG system whose feedback options were disabled. This procedure produced one-minute summaries of bandwidth amplitudes for Delta (.1 – 3.0 Hz), Theta (4 – 7 Hz), Alpha (8 – 12 Hz), LoBeta (SMR, 12 – 15 Hz), Beta (15 – 18 Hz) and High Beta (18 – 40 Hz). Amplitudes for bandwidths were examined for increases and decreases in amplitude as predicted by the MindReflector protocols. Specific statistical analyses were performed on changes in amplitude of the bandwidths that were being trained up – Alpha for Meditative Relaxation training and LoBeta and Beta, since the Quiet Focus training straddled these two bandwidths.

Results

Table 1

Quiet Focus Training (Augmenting 13.0 – 16.75 Hz)

First vs. second half mean Hz comparisons for MindReflector attention training (C3 and C4 recordings were averaged)

	First half	Second half	Met Prediction?	
			Yes	No
S1	3.41	3.71	X	
S2	3.22	3.47	X	
S3	2.27	3.78	X	
S4	1.82	1.90	X	
S5	3.92	4.25	X	
S6	2.06	2.27	X	
S7	1.94	1.96	X	
S8	4.07	4.86	X	
Sum	22.71	26.20	16/16	
Mean	2.84	3.28	Chi Square 7.574 p< .01	

Paired t-tests: $t = 2.5083$, $p = .0405^*$

Table 2

Meditative Relaxation Training (Augmenting 7.5 – 9.25 & 10.0 – 11.75 Hz)

First vs. second half mean Hz comparisons for MindReflector relaxation training

	First half	Second half	Met Prediction?	
			Yes	No
S1	4.91	5.50	X	
S2	8.40	9.16	X	
S3	4.14	4.60	X	
S4	2.50	3.34	X	
S5	9.84	10.38		1/2
S6	3.58	3.14		1/2
S7	3.08	3.02		X
S8	-----	-----		-----
Sum	22.71	26.20	10/14	
Mean	2.84	3.28	Chi Square 1.348 p> .30	

Paired t-tests: $t = 2.1860$, $p = .0715$

Table 3

First vs. second half comparison

Attention Training (Augmenting 13.0 – 16.75 Hz)

Success at predicting highest and lowest mean values of trained-up bandwidths
For C3 and C4 recordings, with N = 8

Prediction:	Yes	No	Chi Square	Prob.
Lowest LoBeta value will occur in first half	12	4	2.133	p>.15
Lowest Beta value will occur in first half	13	3	3.463	p = .06
Highest LoBeta value will occur in second half	12	4	2.133	p>.15
Highest Beta value will occur in second half	14	2	5.236	p<.05

Table 4

First vs. second half comparison

Relaxation Training (Augmenting 7.5 – 9.25 & 10.0 – 11.75 Hz)

Success at predicting highest and lowest mean values of trained-up bandwidths
For C3 and C4, with N = 7

Prediction:	Yes	No	Chi Square	Prob.
Lowest Alpha value in first half	13	1	6.3	p<.02
Highest Alpha value in second half	10	4	1.347	p = .06

Table 5

**BrainMaster (C3/C4) amplitude score comparisons
for initial and final three minute of MindReflector training**

Attention Training

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

		Delta	Theta	Alpha	LoBeta	Beta	HiBeta
S1	Initial Mean Hz	18.55	7.82	8.40	3.76	3.52	1.72
	Last Mean Hz	19.21	8.62	8.99	4.02	3.74	1.86
S2	Initial Mean Hz	4.24	3.57	3.10	1.90	2.05	3.12
	Last Mean Hz	3.67	3.32	2.99	1.94	1.96	2.97
S3	Initial Mean Hz	6.38	3.59	2.56	1.74	1.59	2.44
	Last Mean Hz	4.92	2.92	3.61	2.14	1.72	2.76
S4	Initial Mean Hz	7.54	5.26	3.56	2.22	2.00	3.00
	Last Mean Hz	10.41	6.24	5.26	4.12	4.84	5.12
S5	Initial Mean Hz	8.10	5.15	3.96	2.18	1.86	2.48
	Last Mean Hz	8.67	5.08	3.58	2.47	2.32	3.25
S6	Initial Mean Hz	8.84	5.23	4.46	3.23	2.94	3.32
	Last Mean Hz	16.56	7.88	5.22	3.54	3.60	4.72
S7	Initial Mean Hz	6.10	4.35	6.94	3.42	2.15	3.82
	Last Mean Hz	6.41	4.24	8.58	4.07	3.40	5.14
S8	Initial Mean Hz	8.36	4.74	5.98	3.68	3.92	----
	Last Mean Hz	7.24	4.39	6.63	4.79	4.98	----

Sum of initial three -minute averages = 22.13 20.01
Mean = 2.77 2.50

Sum of final three-minute averages = 27.09 26.54
Mean = 3.39 3.32

Paired t-test results for LoBeta: $t = 2.8781$ $p = .0237^*$
Paired t-test results for Beta: $t = 2.4647$, $p = .0432^*$

Beta testing Summary

Procedure and subjects

Eight volunteer subjects were given the opportunity to use and record their responses to the four protocols of the MindReflector system, in exchange for being able to keep the MindWave headset and the MindReflector software after the Beta testing was over. Only five subjects returned their booklets on time. Subjects included one 11-year-old girl with a chronic sleeping problem, and one female and three male adults, ages 53 – 72. All four adults had been patients of the present psychologist with problems from anxiety to cognitive sequelae of a stroke.

Results

Completed booklets were returned by five of the participants.

1. Overall, all users enjoyed the system, with Quiet Focus and Alpha Theta being cited as the most enjoyable.
2. Most subjects indicated the system was easy to use.
3. The 11-year-old subject cited boredom as the worst quality of the experience. Adults appeared to enjoy it more, especially when they could personalize the feedback with Windows Media Player.
4. Top three positive adjectives cited for **Quiet Focus** were calm, relaxed and focused.
5. Top three positive adjectives cited for **Meditative Relaxation** were relaxed, calm and peaceful.
6. Top three positive adjectives cited for **Full Spectrum** were relaxed, focused, and calm and centered (tied). Not surprisingly, Full Spectrum was by far the most difficult protocol.
7. The top three positive adjectives cited for **Alpha Theta** were relaxed, calm, and peaceful and focused (tied).
8. Negative responses, although actively solicited, were few. “Bored” was the most common and came from the 11-year-old pre-teen. Full Spectrum elicited the most negative responses, all related to difficulty getting it to work smoothly. It requires a lower difficulty setting. Agitated, irritable, frustrated, anxious and annoyed were cited, but only 1 – 3 times. Agitated was cited three times, but comments that followed indicated they felt better once the difficulty was reduced. The majority of participant still cited the experience as enjoyable. No long-term negative effects were cited.

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Beta testing comments

1. Stops my mind from racing.
2. "Love it." If you need a testimonial, let me know.
3. Helps me sleep.
4. Helps me focus.
5. Gives me more energy.
6. Reduces my worry and anxiety
7. Calms me. I felt peaceful at the end of training.
8. I love it. I will use it often.
9. I seemed more relaxed after training.
10. Perfect way to decompress
11. Very relaxing
12. Hypnotic
13. Calming.
14. After training I am more focused and alert.
15. After training, I slept well through the night.
16. Refocused my attention.
17. When I lost focus, it stopped and got me to focus again.
18. Caught myself nodding off.
19. Focused at first, but I got bored and sleepy,

BETA TESTING FEEDBACK SHEET SUMMARY

Feedback from five Beta testers using the protocol at least three times a week

Training Protocol: QUIET FOCUS

Response to training:

After training I felt:

___ 15 ___ Relaxed	_____ 0 ___ Agitated
___ 16 ___ Calm	_____ 0 ___ Excited
___ 10 ___ Focused	_____ 0 ___ Irritable
___ 3 ___ Centered	_____ 2 ___ Sad
___ 0 ___ Happy	_____ 1 ___ Upset
___ 5 ___ Self-confident	_____ 0 ___ Angry
___ 0 ___ Integrated	_____ 0 ___ Frustrated
___ 7 ___ Attentive	_____ 0 ___ Anxious
___ 3 ___ Clear	_____ 0 ___ Annoyed
___ 1 ___ Spiritual	_____ 2 ___ Bored
___ 7 ___ Determined	_____ 0 ___ Worried
___ 5 ___ Peaceful	_____ 1 ___ No Difference
___ 1 ___ Connected	
___ 1 ___ Open	

I found the training:

___ 1 ___ Difficult ___ 14 ___ Enjoyable ___ 10 ___ Easy ___ 3 ___ Boring

Training Protocol: MEDITATIVE RELAXATION

Response to training:

After training I felt:

___ 18 ___ Relaxed	_____ 0 ___ Agitated
___ 14 ___ Calm	_____ 0 ___ Excited
___ 5 ___ Focused	_____ 0 ___ Irritable
___ 5 ___ Centered	_____ 0 ___ Sad
___ 1 ___ Happy	_____ 0 ___ Upset
___ 6 ___ Self-confident	_____ 0 ___ Angry
___ 1 ___ Integrated	_____ 0 ___ Frustrated
___ 6 ___ Attentive	_____ 0 ___ Anxious
___ 2 ___ Clear	_____ 0 ___ Annoyed
___ 0 ___ Spiritual	_____ 3 ___ Bored
___ 5 ___ Determined	_____ 0 ___ Worried
___ 8 ___ Peaceful	_____ 1 ___ No Difference
___ 1 ___ Connected	
___ 1 ___ Open	

I found the training:

___ 5 ___ Difficult ___ 9 ___ Enjoyable ___ 11 ___ Easy ___ 4 ___ Boring

Training Protocol: FULL SPECTRUM

Response to training:

After training I felt:

___ 17 ___ Relaxed	_____ 3 ___ Agitated
___ 7 ___ Calm	_____ 0 ___ Excited
___ 9 ___ Focused	_____ 1 ___ Irritable
___ 7 ___ Centered	_____ 0 ___ Sad
___ 0 ___ Happy	_____ 0 ___ Upset
___ 4 ___ Self-confident	_____ 0 ___ Angry
___ 3 ___ Integrated	_____ 2 ___ Frustrated
___ 5 ___ Attentive	_____ 2 ___ Anxious
___ 4 ___ Clear	_____ 2 ___ Annoyed
___ 0 ___ Spiritual	_____ 2 ___ Bored
___ 5 ___ Determined	_____ 0 ___ Worried
___ 6 ___ Peaceful	_____ 3 ___ No Difference
___ 1 ___ Connected	
___ 0 ___ Open	

I found the training:

___ 7 ___ Difficult ___ 10 ___ Enjoyable ___ 4 ___ Easy ___ 3 ___ Boring

Training Protocol: ALPHA THETA

Response to training:

After training I felt:

___ 15 ___ Relaxed	_____ 1/2 ___ Agitated
___ 11 ___ Calm	_____ 1 ___ Excited
___ 9 ___ Focused	_____ 0 ___ Irritable
___ 5 ___ Centered	_____ 0 ___ Sad
___ 2 ___ Happy	_____ 0 ___ Upset
___ 1 ___ Self-confident	_____ 0 ___ Angry
___ 1 ___ Integrated	_____ 1/2 ___ Frustrated
___ 7 ___ Attentive	_____ 0 ___ Anxious
___ 0 ___ Clear	_____ 0 ___ Annoyed
___ 0 ___ Spiritual	_____ 4 ___ Bored
___ 4 ___ Determined	_____ 0 ___ Worried
___ 9 ___ Peaceful	_____ 1 ___ No Difference
___ 0 ___ Connected	
___ 0 ___ Open	

I found the training:

___ 2 ___ Difficult ___ 13 ___ Enjoyable ___ 5 ___ Easy ___ 3 ___ Boring

Efficacy Testing for Attention Training

A 25-year-old woman with a history of traumatic brain injury and significant attention difficulties volunteered to take part in intensive training with the MindReflector™ MindWave trainer. Prior to testing, she took part in IVA+Plus CPT testing. After using the Quiet Focus protocol at least five-times-a-week for five weeks, the IVA+Plus was re-administered. Results of pre- and post-training testing are presented below.

Baseline IVA+ Test Results

Date of testing: 7/10/12

All results were considered valid

Evidence of mild Fine Motor Hyperactivity

Full Scale Response Control Quotient = 81 Full Scale Attention Quotient = 20
Auditory RCQ = 65 Visual RCQ = 103 Auditory AQ = 16 Visual AQ = 40

Sustained Auditory Attention Quotient = 0

Sustained Visual Attention Quotient = 48

Follow-up IVA+ Test Results

Date of testing: 9/12/12

All results were considered valid

No evidence of any Fine Motor Hyperactivity

Full Scale Response Control Quotient = 94 Full Scale Attention Quotient = 56
Auditory RCQ = 83 Visual RCQ = 106 Auditory AQ = 56 Visual AQ = 65

Sustained Auditory Attention Quotient = 48

Sustained Visual Attention Quotient = 76

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 augmentation.
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



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