# EEG Training User Guide: Meditation Support Protocol

## Contents

# 1 Introduction

This guide describes how to use the Mind-Body Training Tools (MBTT) Meditation Support EEG Training application. It focuses on how to use the software rather than how to meditate.

Many of the features of this application are the same as those used in the MBTT standard-form protocol EEG training. Therefore I recommend you read the main MBTT EEG Training User Guide first, as here I will assume prior knowledge of the MBTT standard EEG training, and do not explain the common features in any great depth.

I developed the application to support my personal meditation practice. My hope was that EEG neurofeedback could be used essentially to flag up distractions, or mind-wandering. I found that it at least partially succeeds in this aim.

There are two versions of the application, one of which is based on one channel of data, while the other uses two channels. They track different EEG parameters but otherwise are substantially the same. The differences are described more fully in section 1.4 below.

## *1.1 About Meditation*

The term meditation covers a broad range of practices. In general meditation aims to develop certain states of mind, but the specifics vary between practices. For example, *metta bhavana* practice aims to develop *metta* or loving-kindness.

The MBTT meditation support app aims to support the development of the following qualities:

- stillness – the mind is unruffled by mental chatter
- lucidity and clarity – awareness has a clear vivid quality, as opposed to fogginess or sleepiness
- strong, stable presence – as opposed to absent-minded day-dreaming
- calmness, relaxation – practice should ideally feel easy and free and open and (in some sense) effortless.

Anyone who has meditated knows that the mind will sooner or later drift into distraction. The practice of mindfulness is to notice when this has happened and simply bring the mind back to the focus without judgements. However this is not easy, because by definition when you're distracted you're not really present, and not noticing what is going on.

The application aims to support meditation practice by making it easier to notice when the mind has wandered. This is possible to the extent that a distraction is embodied in a brain state change that can be measured and fed back in real time.

What happens to brain state when we get distracted? What can we measure in EEG? Or conversely, when meditative concentration goes well, how does this show up in brain state?

Before answering these questions, we need to consider what happens at the level of mind, or subjective experience.

## *1.2 The Nature Of Distraction*

There are many forms of distraction, so I'll speak in broad terms.

One thing that can happen is that the mind becomes over-aroused or agitated or restless, perhaps emotionally anxious because we have turned to our recurrent worries. The mind lacks stillness – in a sense it has too much energy or at least too much course, agitated energy.

Another form of distraction is that we can sink into a dull, passive, day-dreamy state where the

mind just drifts rather aimlessly or without direction. In a way this is the opposite kind of distraction, where the mind is characterised by low energy and lack of clarity and sharpness. In the extreme the mind can become foggy or sleepy.

In this state the mind likely engages in “mind chatter” – holding imaginary conversations or re-running old conversations, or perhaps planning the future in some way. This mental activity is not purposeful or consciously directed – it's like a radio is playing in the mind. We've lost our “presence”.

Neuroscience tells us this kind of mind-chatter is accompanied by activation of a brain circuit known as the *default mode network*.

## *1.3 Meditation As The Middle Way*

Meditation is a balanced state. We can think of this balance in at least two ways:

- balanced arousal: not over-aroused or agitated, not under-aroused or day-dreamy or sleepy.
- balanced effort – a middle way between wilfulness and apathy, or balanced control: not over-controlling, not under-controlling.

We can express this idea of balance using the Human Performance Curve (HPC) or Yerkes-Dodson law – see figures 1 and 2 below. First in terms of arousal:

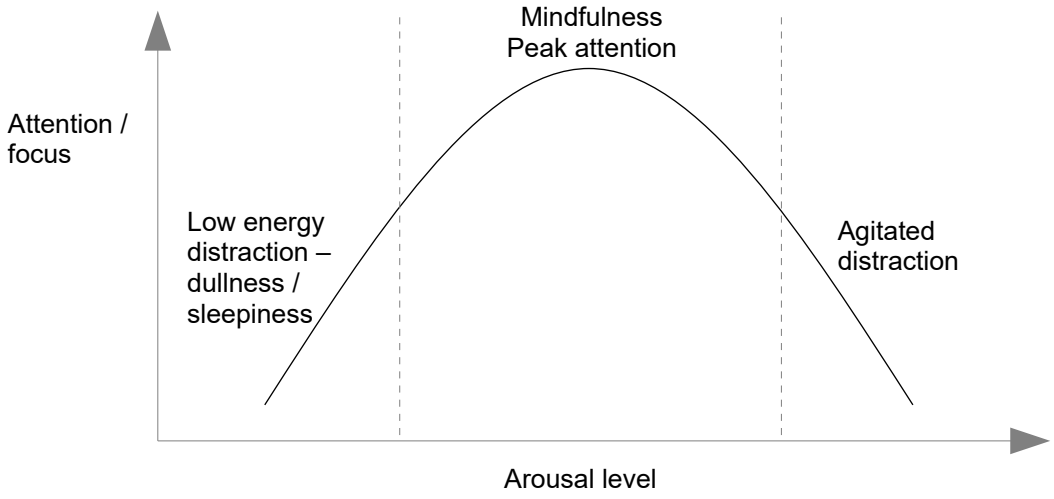


Figure 1 – the Human Performance Curve (Yerkes-Dodson law) adapted to meditative attention / focus

And second, in terms of effort or the nature of mental application:

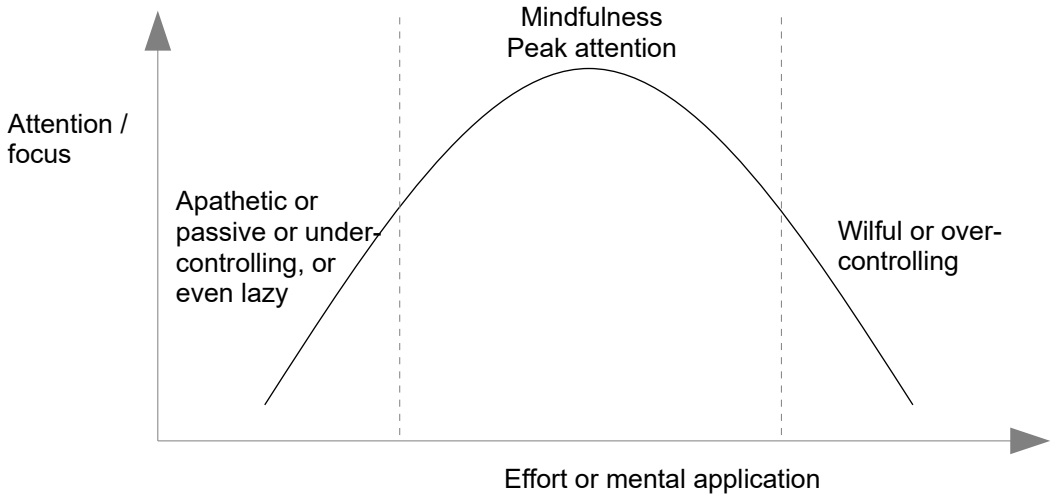


Figure 2 – the Human Performance Curve (Yerkes-Dodson law) adapted to meditative attention / focus

Now we can reframe our earlier question as: what brain state changes characterise each of these two poles of the HPC: agitated and / or wilful, versus dull and / or passive?

## *1.4 Feedback Parameters*

The Meditation Support application offers feedback of two parameters, one designed to capture shifts towards agitated and/or wilful distraction, the other for shifts towards dull and/or passive distraction.

In the design of the, I attempted to select parameters derived from the measured EEG signal, that would adequately differentiate these shifts, and I believe I have succeeded to some extent, though not perfectly. In this guide I will set out which EEG parameters I chose, then explain why they work as distraction detectors.

As stated in the introduction above, there are two versions of the Meditation Support Protocol. They differ in their choice of the parameter to capture dull / passive shifts. One of the two requires two channels of data, the other just one.

### 1.4.1 Sensor Placement

Although the software itself does not dictate where you should place the electrodes, I designed and tested the application using a forehead placement, with the active sensors at something like F3-F4 (using the 10-20 system). I don't think it matters if the placement is not exact – e.g. Fp1-Fp2, or anywhere between, can work, or even F7-F8. However I do recommend placing the active sensors symmetrically on the head.

In the one-channel version I use a bipolar placement – i.e. both the active and the reference electrodes are on the scalp and picking up brain activity. This means that the biofeedback device is measuring the difference between the two sites.

### 1.4.2 Agitated or Wilful Distraction

Agitation and / or wilfulness can manifest quite simply as muscle tension. When we're “trying too hard” or applying ourselves overly forcefully, we tighten up in the face and head. Similarly, if the mind turns to emotionally-stimulating memories, or worries about the future, we tend to tighten up in the face and head.

The application therefore tracks the amplitude over a range of 30 to 127 Hz. This is a broad frequency range extending far beyond the normal EEG range (which is about 1 to 40 Hz) and by far the biggest contributor is muscle activity. Although typically EMG biofeedback uses a frequency range going much higher, (e.g. 100-200 Hz) I chose the cut-off of 127 Hz so that the application could work with devices sampling at 256 Hz.

Placing two sensors symmetrically on the forehead picks up activity in muscles throughout the head, including the face and jaw. It works well as a generalised stress measure. Even inner self-talk can manifest because we may be using speech muscles subliminally, in inner speech.

Both the one- and two-channel versions track this same parameter – in the case of the two-channel app the two channels are averaged into a single parameter.

### 1.4.3 Dull or Passive Distraction

The protocols here are more challenging to explain. I will describe my choice, then explain why it works (in theory).

#### 1.4.3.1 One-channel Version: Down-training 1-20 Hz Amplitude

With a bipolar placement at the front of the head, there are two major sources for the measured signal: (i) eye movements and (ii) brain activity or true EEG.

Normally, eye movements are regarded as undesirable artefact, to be minimised. A frontal bipolar placement picks up eye blinks but especially lateral eye movements make a big contribution. This is actually useful because the eyes tend to jiggle around (non-volitionally) when we have drifted out of sharp focus and into “default mode” mind-wandering. Remember, from a practical point of view we only wish to detect distraction, and it doesn't really matter if we detect it directly in the brain or indirectly. Conversely, when there is a clear focus with a strong, vivid sense of presence, the eyes are relatively still.

Because the parameter does pick up eye blinks it is best to train / practise with eyes closed.

The component from true EEG is also a useful measure. As I said earlier, with a bipolar placement you are measuring the difference between the two sites. Research suggests that in the meditative state, EEG rhythms become synchronised across the brain, and particularly between the two hemispheres. In such a state the difference between hemispherically-symmetrical sites such as F3-F4 becomes small. (This synchronisation is most notable in the alpha range but seems to occur in other parts of the spectrum too.)

It's true that in principle the brain could reduce this bipolar amplitude either by increasing synchrony, or by suppressing the EEG at both sites. The brain tends to suppress slow frequencies when you need clear alertness. So either way, down-training the bipolar amplitude makes sense.

It's hard to know how each of the two sources (eye movement and brain activity) contribute to the signal, relatively. But again for practical purposes it doesn't matter – what counts is effectively detecting distractions. In my personal experience this protocol does quite well at detecting “default mode” mind-wandering – but it isn't perfect.

#### 1.4.3.2 Two-channel Version: Training Up Gamma (35-45 Hz) Synchrony

Professor Richard Davidson is a neuroscientist who, as part of a collaboration with the Dalai Lama,

has researched the brains of some of the world's most experienced meditators, mainly from Tibet. His EEG brain mapping studies revealed a clear trait: the meditators showed synchronised gamma activity across the whole brain, much more strongly than non-meditating controls, especially during the practice of meditation. It therefore makes some sense in principle, to use gamma synchrony as a neurofeedback parameter.

Gamma typically refers to a range of 35-45 Hz, or sometimes extending higher. A significant potential problem is that muscle activity shows up in this range too. There is little point in attempting to up-train simple gamma amplitude.

For the purposes of the Meditation Support app, I implemented a gamma synchrony protocol that is relatively independent of gamma amplitude. My own experience of training with it, is that it seems to correlate with meditative focus, at least to some extent, though it is a rather labile parameter.

It must be said that the gamma synchrony protocol is somewhat experimental in nature.

## *1.5 How To Apply The Mind During Training*

The following is based on my own subjective impressions of training myself (i.e. practising mindfulness meditation with the support of neurofeedback).

It's worth repeating the qualities of mind which I set out to support, when I developed the application:

- stillness – the mind is unruffled by mental chatter
- lucidity and clarity – awareness has a clear vivid quality, as opposed to fogginess or sleepiness
- strong, stable presence – as opposed to absent-minded day-dreaming
- calmness, relaxation – practice should ideally feel easy and free and open and (in some sense) effortless.

I would say it definitely takes effort to develop this lucid presence – but a particular kind of effort. It's not forceful effort, or at least not overly-forceful effort, but a calm yet strong intent. It's an intent to be clear and lucid. Not a grit-your-teeth effort but a relaxed effort that is not attached to results. I prefer to call it mental application rather than effort.

The focus can be on sensory experience. It doesn't seem to matter that much if it is auditory experience or kinaesthetic experience or even visual experience.

I find that a sense of open-minded curiosity is helpful. In your mind, hold the question, “what is my mind doing?” or “what is happening in my awareness?”, or “what is going to happen next in my awareness?”. So a sort of open-minded waiting – as though something were going to happen but you don't know what, or when. A perfectly patient waiting. In my experience, default mode mind-wandering happens when a sense of boredom with the present moment comes in, or when we decide we already know about it and don't need to pay attention. The idea of “beginner's mind” is an appropriate one.

I look for a broad, open, balanced focus as opposed to a narrow focus. For example, in the kinaesthetic sense I look to balance my awareness between left and right, and a sense of space around me. In this I'm no doubt influenced by the “open focus” method developed by Les Fehmi.

### 1.5.1 Attitude To Feedback

When you hear the feedback change, that is your cue to invoke your curiosity: what just happened in your mind? Perhaps you will find that you started to become distracted – or perhaps not. The parameters are not fool-proof as distraction detectors. Sometimes the EEG shifts seem to be

somewhat random.

Of course if your mind had wandered, you should non-judgementally return to lucid presence and focus. Becoming frustrated or anxious or self-critical is not helpful.

If the feedback told you you had tightened up, you can take steps to relax – moving back towards the centre of the Human Performance Curve. If you had drifted into default-mode dullness, you can gently rekindle your sense of presence and lucidity.

## 1.6 Audio Feedback

The app is designed to support eyes-closed meditation practice, so focuses on audio feedback. The audio feedback is described more fully in section 3.2 below, but in summary there are two soundtracks (one for each of the two main EEG parameters) which play with variable volume. The volume tracks the EEG parameter. For the EMG or muscle tension parameter, you can also play midi notes (a sort of bell sound) when the muscle tension signal exceeds a threshold.

The audio feedback works much like some of the screens available for the standard-form protocols.

## 1.7 Threshold Controls

Thresholds are used to precisely control how and when feedback is delivered – i.e. what specific level of the EEG parameters is required to invoke the feedback.

There are two threshold controls in the Meditation Support app, one for each of the feedback parameters. They work in much the same way as the standard-form EEG training – though with slight differences.

Setting the threshold levels appropriately is key to the success of neurofeedback training.

Section 3.1.5 below describes how to operate the threshold controls.

## 1.8 Calculation of Amplitudes

This is a technical note to explain how the software calculates amplitudes. Since training is a matter of relative change, the actual numbers hardly matter and this section can easily be skipped.

The application uses digital bandpass filters, one for each of the main parameters. The software takes the magnitude of the filter's output. (This output is oscillating between positive and negative values and would otherwise average out to zero.) Then this magnitude is averaged over a period of a few seconds.

This amplitude calculation is different from the peak-to-peak amplitude, and even from zero-to-peak amplitude (it is approximately 0.64 x peak amplitude, or 0.32 x peak-to-peak amplitude). It also differs very slightly from RMS amplitude.

# 2 The MBTT Platform Application

As stated in other guides, Mind-Body Training Tools consists of a set of applications built using BioEra, plus the Platform application, which manages and launches the training applications, and the data they generate. So the Platform application is the starting point.

Each MBTT module has its own tab in the Platform app, and EEG Training is no exception. The EEG training tab is shown in figure 3 below.

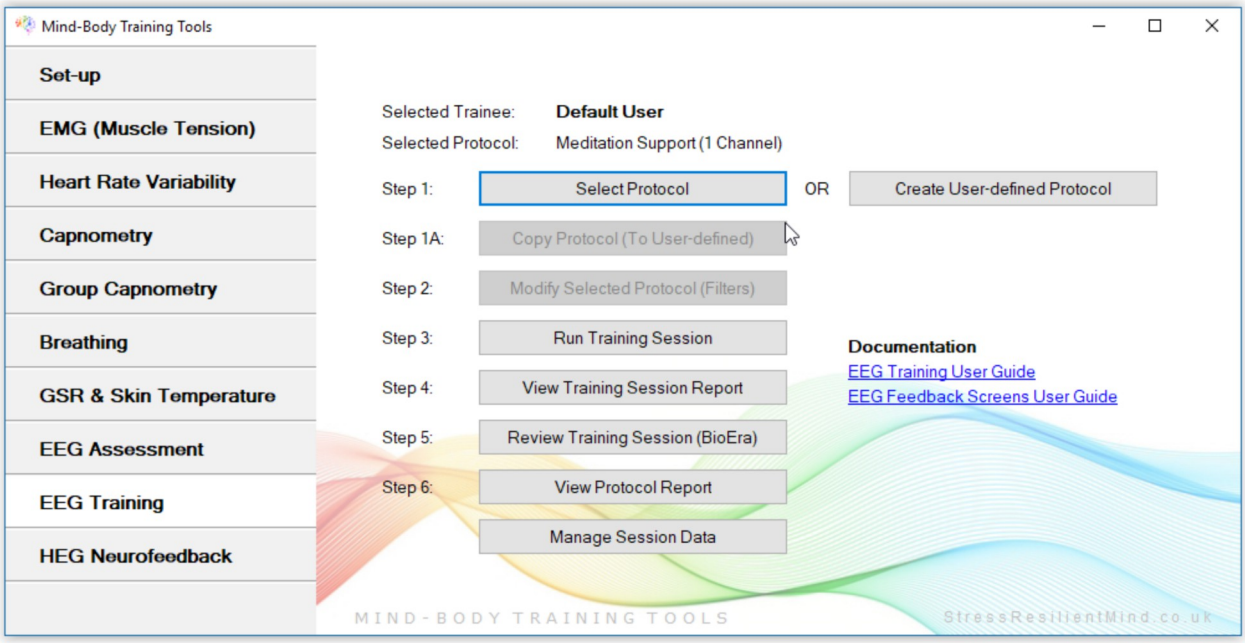


Figure 3 – EEG Training tab of the Mind-Body Training Tools Platform application

To run a session with the Meditation Support app, first you need to select the protocol, by clicking on the button “Select Protocol” (Step 1, in figure 3 above). This opens up a dialog window showing lists of protocols organised under three tabs. The Meditation Support protocols are listed under the “non-standard” tab (see figure 4 below).

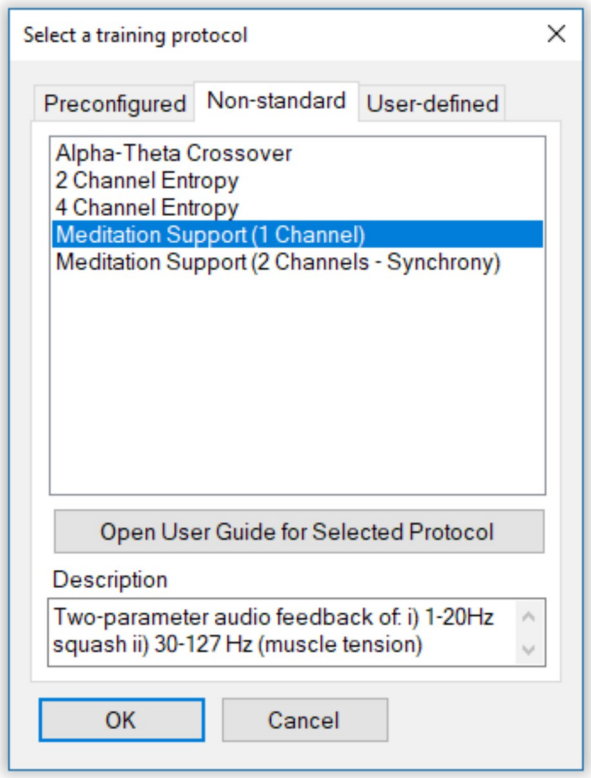


Figure 4 – Select protocol dialog

As explained earlier, there are two versions, based on one and two-channel EEG. Select one of them from the main box in the dialog, then click OK to close the dialog.

At this point, you can either run a new session (step 3 in the main EEG Training tab) or view data from previous sessions (i.e. create reports). The buttons for steps 4 onwards are for report generation and data management, and these functions are covered in section 4 below.

You can't edit the protocol in the same way as for standard-form protocols (i.e. outside of training sessions), but you can adjust the filters used in the protocols (see section 3.1.3 below).

## 2.1 Running A Live Training Session

To launch a live training session, click the button “Run Training Session” (step 3). This opens another dialog window, shown below in figure 5.

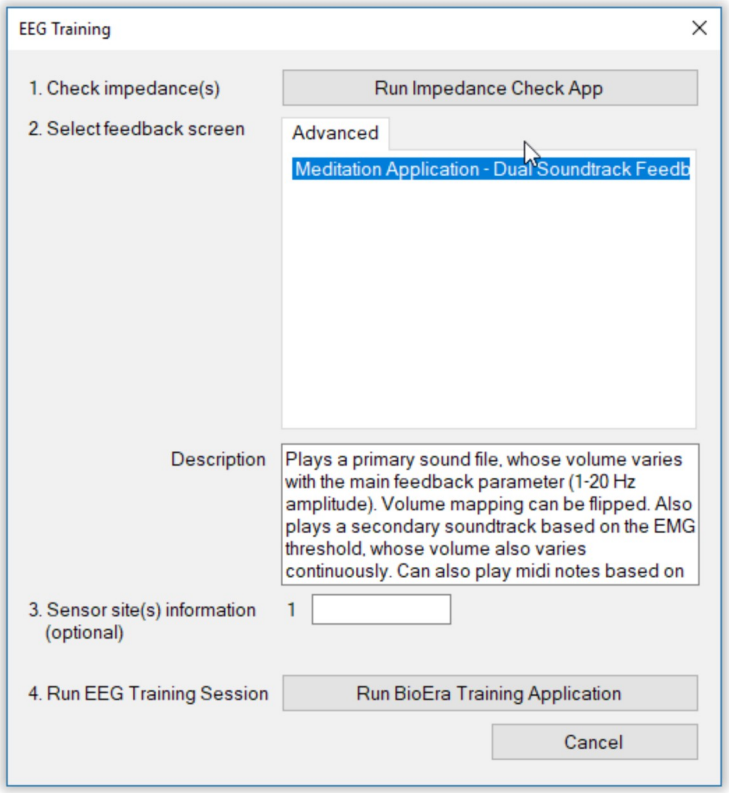


Figure 5 – Run training session dialog

It is strongly recommended that you check the quality of your EEG hook-up by testing impedance – click the button “Run Impedance Check App” at the top of the dialog, step 1.

Explaining impedance checking is beyond the scope of this guide, but it should be said that this function in MBTT is dependent on what type of amplifier you are using. Not every amplifier has an impedance checking tool built into MBTT, but you should still check impedance using another means.

There is currently only one feedback screen available for the Meditation Support application, so accept this default at step 2 in the dialog.

You can optionally record the site(s) on the scalp you're recording from (step 3 in the dialog). This does not affect the software operation, but it is recorded and shown in reports.

Click the button “Run BioEra Training Application” (step 4) to launch the live training session. This opens a BioEra app, which is described in detail in the following section.

# 3 The BioEra Training Application

As stated in other documentation, live biofeedback and neurofeedback work is done using a third-party software called BioEra. The Meditation Support app is built as a BioEra design. This app has two windows, much as the standard-form protocol apps do. One is the control screen, the other the feedback screen.

## *3.1 Control Screen*

Figure 6 below shows the control screen window (in this case the two-channel version).


Figure 6 – Control screen of the alpha-theta training application

### 3.1.1 Controls Common To Standard-form EEG Training

The following controls are explained more fully in the main EEG Training User Guide:

- Start, stop, freeze buttons (1 in figure 6)
- Session time display (2 in figure 6)
- Event marker (3 in figure 6)
- Data epoch (drop down list – 4 in figure 6) – sets how often data is written for the session summary report
- Training period controls: duration drop-down list, begin and stop buttons (5 in figure 6).

### 3.1.2 Raw EEG Display

The uppermost chart(s) (7 in figure 6) shows the raw EEG – it is always useful to see this, in part to know that you have a clean EEG.

The two-channel version of the protocol shows two traces, one for each channel, while the one-channel version shows a spectral display in place of the second channel raw trace. In this respect it's the same as the standard-form protocols.

Drop-down list controls, situated above the chart, set the range (vertical scale) and the time period (horizontal scale) of this chart (or charts).

### 3.1.3 Filter Controls

You can set the properties for the filters used to calculate the feedback parameters. Filters are described in more detail in the main EEG Training User Guide. The main settings are the upper and lower frequency cut-offs, but there are others besides.

There are buttons (6 in figure 6) which open up a filter properties dialog.

I don't anticipate many users will want to take advantage of this feature, but it is there for those who do.

### 3.1.4 Main Trend Display

The largest chart, in the centre of the control screen, (8 in figure 6) shows the variation of the two feedback parameters over time.

Each parameter has an independent range (vertical scale) although only one is displayed at a time. Click the coloured squares just above the chart to switch which one is active.

Each range is exactly the same as the bar chart which is part of the thresholds (see section 3.1.5 below). The thresholds have controls for adjusting the range (and of course each is controlled independently).

### 3.1.5 Threshold Controls

To recap, thresholds are used to precisely control how and when feedback is delivered, or more specifically, over what range of the EEG parameters the feedback varies.

The Meditation Support app uses two thresholds, one for each of the feedback parameters. They work in much the same way as the thresholds in the standard-form training. The EMG threshold has some differences, relating to automatic setting of the threshold levels.

#### 3.1.5.1 Parameter 1 Threshold

In the one-channel application, parameter 1 is 1-20 Hz amplitude, while in the two-channel application, it is gamma synchrony. In figure 6 above, this threshold is labelled 9. Figure 7 below shows it again, in this case the (two-channel) synchrony version.

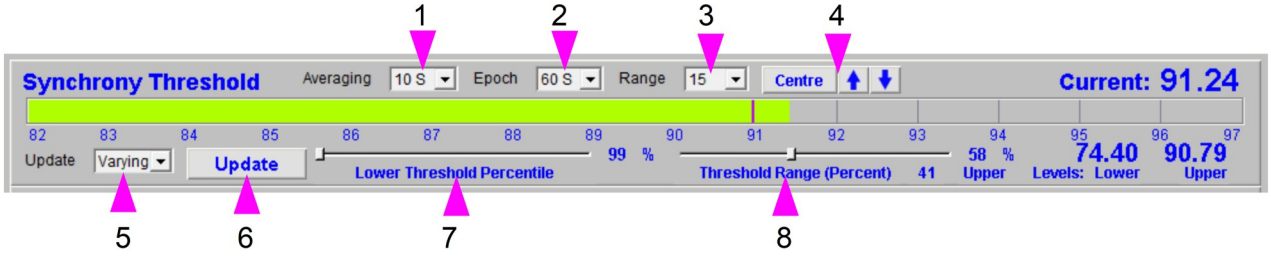


Figure 7 – Parameter 1 threshold and controls

There are drop-down list controls for setting the averaging period, the epoch (over which automatic threshold levels are calculated) and display range. This latter applies both to the horizontal bar chart that is part of the threshold controls, plus the main trend display (section 3.1.4 above). The displayed range can be shifted up and down to fit the signal to the chart, using the buttons labelled 4 in figure 7.

The threshold levels can be updated in exactly the same ways as in the standard-form training application.

#### 3.1.5.2 EMG Threshold

The EMG threshold works in the same way as other thresholds except that the controls for automatically setting the upper and lower levels are different. This is because the nature of the variation of the EMG parameter is different. Mostly, it is fairly stable (varying little) until there is a movement, or some other event, when it can change significantly.

You can see this in the main trend display in figure 6 above, where the blue EMG trace shows a two sharp spikes. These spikes are caused by swallowing.

The actual numbers for this parameter, delivered by the application, are also relatively consistent, so that we can say when the head and face are fully relaxed, the EMG level is around 0.5 or less. If your level is higher, you may be holding tension somewhere.

Figure 8 below shows the EMG threshold and controls.

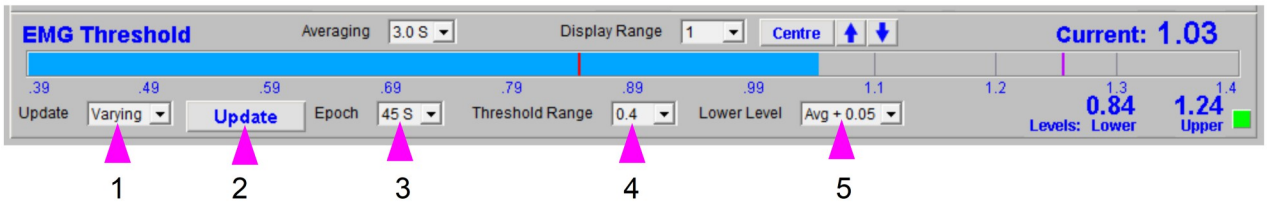


Figure 8 – EMG threshold & controls

#### Automatic Threshold Level Calculation

Instead of basing the threshold levels on percentiles as in other applications, the threshold has a set range, i.e. a set interval between upper and lower levels, which is set by the drop down list control 4 ("threshold range") in figure 8. The precise positioning is set a little above the average level of the parameter, via drop down list control 5 in figure 8.

This means that when muscle tension is hovering around its average, no feedback is given, but the feedback does come in when tension rises much above this average. Section 3.2 below describes feedback in more detail.

Of course you can still move the threshold level "by hand" i.e. by dragging them with your mouse.

## 3.2 Feedback Screen

The feedback screen is the second of the application's two windows, and is shown in figure 9 below.

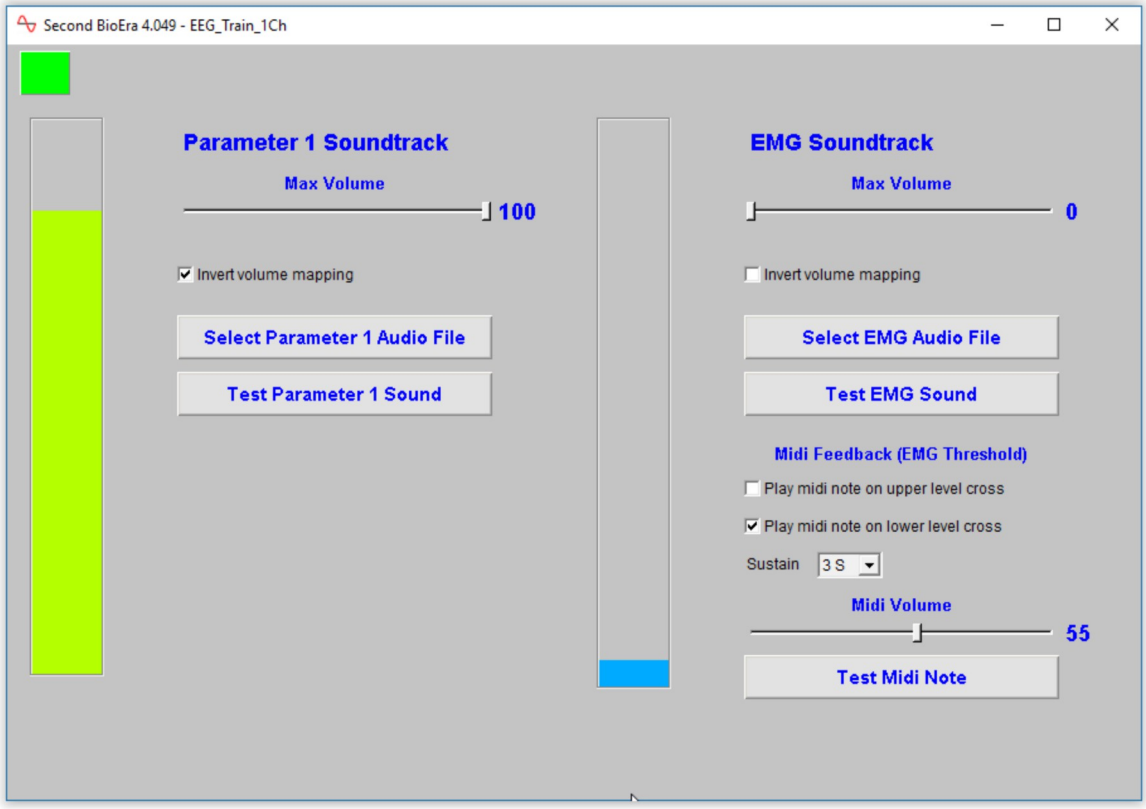


Figure 9 – Feedback screen

The feedback screen is similar to some of those available in the standard-form application. There are controls for configuring each of the two feedback parameters. The left side of the screen is devoted to parameter one (either 1-20 Hz amplitude or gamma synchrony) while the right side is devoted to EMG feedback.

Again the application is designed for eyes-closed training / practice, so the primary form of feedback is auditory. However there is a simple bar chart for each parameter. The range of each bar is set by the upper and lower threshold levels in the control screen.

## 3.3 Audio Feedback

Each feedback parameter has a soundtrack whose volume varies with the parameter. Additionally, the EMG parameter has midi feedback available – see section 3.3.1 below.

The soundtrack feedback can be configured in different ways. You can either have the sound play as a reward for attaining the desired state, or as a warning that you are drifting out of it. If the latter, then you can consider silence as the reward, which seems appropriate in a context of meditation practice (this is my personal preference when training myself).

Depending on this choice, you can opt to invert the soundtrack feedback using the checkbox control, “invert volume mapping” (there is one for each soundtrack). Checking this option means that the soundtrack plays louder, the lower the feedback parameter falls (otherwise volume

increases proportionally to the parameter).

Using the one-channel application, you are training down parameter one, which means that if you want to reward positive progress (parameter going lower) then you should check the option so that the sound gets louder the lower the signal goes.

Since in the two-channel version you are training up gamma synchrony, you need the opposite setting to achieve the same effect of rewarding positive progress.

### 3.3.1 Midi Feedback (EMG Parameter)

Discrete midi feedback is available for the EMG parameter, in addition to the soundtrack feedback already described. This is because, as mentioned earlier, the EMG parameter tends to behave differently i.e. show a different pattern of variation, to other EEG parameters, at least in my experience. I find that once you've learned to relax, it stays pretty low and stable, until there is some emotionally-arousing mental activity, at which point it may rise quickly. For this reason I find discrete feedback preferable.

The midi feedback means that a note is sounded whenever the parameter rises above a threshold limit. The threshold limit is typically based on the average level, as described in section 3.1.5.2 above.

The EMG parameter suffers from artefacts including movements and swallowing. For this reason, there is an extra control, a drop-down list called “sustain”. With this set to say 5 seconds, the parameter must stay above threshold for 5 seconds before the feedback sounds. This is a means of effectively filtering out short-duration movements / muscle activity. Setting it to zero effectively disables this feature.

You can use both forms of audio feedback for the EMG parameter (i.e. midi plus soundtrack) or you can turn either one off, by turning its maximum volume (slider control) down to zero. My personal preference is to use only midi feedback and not soundtrack feedback for the EMG parameter.

### 3.3.2 Media Files

Audio files are not included with MBTT software for reasons of copyright. You need to obtain suitable material for yourself. You can purchase this easily from online retailers such as Amazon or Apple (iTunes).

I have found that nature sounds work well with neurofeedback. For example, I've used a “dawn chorus” soundtrack for reward feedback, and a rain storm soundtrack for aversive (warning) feedback.

The software requires audio files to be in .wav format. However, downloadable audio files are typically provided in .mp3 format, in which case you will need to convert them. Software for conversion is readily available, including some online converters (just google something like “convert mp3 to wav”). Personally I've used a freeware product called *Audacity*, which I have found very helpful, not just for conversion but for sound editing more generally.

Downloaded soundtracks typically have a fade-in and fade-out at the start and end, which is unhelpful for neurofeedback. I recommend using Audacity to edit these out.

# 4 Reports & Data Management

As with the standard-form protocols, MBTT software allows you to manage the data generated by training sessions over time. The report and data management functionality is almost exactly the same, for the Meditation Support application, and I again refer you to the main EEG Training User Guide. Here I will give a very brief summary and comment on the minor differences.

## *4.1 Reports*

You can view reports for individual session, or all sessions over time for the currently selected user.

There are two types of individual session reports: html summary reports (based on a text data file written by the training application) and BioEra-viewable reports based on a .xdf session file.

The html report tracks two parameters. In the one-channel version these are 1-20 Hz amplitude plus EMG amplitude, and in the two-channel version they are gamma synchrony and EMG amplitude.

The BioEra report shows the standard EEG bands – delta, theta, alpha and beta. It has at least a couple of advantages: first, you can zoom in to particular areas of the chart (by dragging your mouse over areas of interest) and second, you can show or hide individual traces such as delta.

## *4.2 Data Management*

You can use the data management functions to delete or archive training sessions, and to email reports to other people, e.g. if you are a coach or therapist working with clients.