EEG Training Guide to Feedback Screens

Contents

1 Introduction

This guide explains the workings of the feedback screens which are available as options within Mind-Body Training Tools (MBTT) EEG Training module.

EEG neurofeedback training in MBTT is described in the main EEG Training User Guide – you should read that document before trying to make sense of this.

1.1 Summary of MBTT EEG Training Design

The EEG neurofeedback practitioner must first decide what to train, i.e. what aspect of EEG such as theta amplitude or alpha coherence – also what direction to train in (i.e. enhance the chosen aspect or inhibit it). This choice of what to train is embodied in the software as the "protocol".

In MBTT most protocols follow a standard form, though there are some special protocols. The feedback screens described in this guide work with standard form protocols only – special protocols have their own forms of feedback.

The user must first select a protocol (or create one), and then launch a training session. Actual training involves the use of the BioEra EEG training application. This has two windows, one aimed at the "practitioner" and known as the control screen, and the other aimed at the "trainee" and known as the feedback screen. (Of course the practitioner and trainee can be one and the same person, if you're training yourself). Essentially, the control screen manages the session, while the feedback screen actually delivers the feedback.

Before you launch the BioEra training app, you must select a feedback screen from a set of options (as described in the main EEG Training User Guide). Each option presents feedback in a different form. For example, some focus on audio feedback (and are suitable for eyes-closed training) while others offer visual feedback.

The feedback screens are independent of protocol, and in principle can work with any protocol.

The feedback available in the feedback screens is only active during training periods.

1.2 Types of Feedback: Continuous and Discrete

These forms of feedback were introduced in the main EEG Training User Guide. To summarise, in continuous feedback some property of the feedback medium such as volume of a sound, varies smoothly over a certain range, and in correlation with the measured EEG parameter e.g. theta amplitude. In that case, the higher the amplitude of theta, the louder the volume of audio feedback.

Discrete feedback takes the form of a distinct event, such as the sound of a bell ringing, or a video either starting to play, or stopping. The feedback event is linked to the EEG parameter via threshold levels – the feedback event is triggered by the EEG parameter crossing some limit which is controlled by the practitioner.

Actually thresholds are also relevant to continuous feedback in that they control the range of variation of the feedback. Thresholds are described in depth in the main EEG Training User Guide.

In MBTT EEG Training (using standard form protocols), feedback screens are grouped into three lists: continuous, points-based (discrete), and advanced (which may be a combination of feedback types).

1.3 Reward & Aversive Feedback

Feedback can either reward the trainee for attaining a desired brain state, or warn of an undesired brain state. Both can be productive forms of learning.

The same feedback screen can in principle be used for either. For example, soundtrack feedback, a sound is played at a volume which varies with the EEG parameter. You could select an unpleasant sound (e.g. wind blowing, or just a white noise hiss) for aversive feedback, or a pleasant sound (e.g. nature sounds or music) for reward feedback.

1.4 Threshold Controls

The configuration of the thresholds is key to success in EEG neurofeedback. Threshold levels need to be set so that e.g. scoring points is neither too easy nor too difficult. The user can of course configure the threshold controls (from the control screen).

To some extent, the decision of how to configure the thresholds depends on your choice of feedback screen – e.g. points-based feedback can have a lower level of averaging (smoothing).

1.5 Threshold Ratio

In many cases, the feedback is calculated using a parameter derived from the main threshold. Explained in the main EEG Training User Guide, it is simply a number which ranges from zero to one, between the two levels of the threshold. When the feedback parameter is exactly at the upper level, the ratio is 1.0, while at the lower level it is 0.0.

Elsewhere, the ratio is calculated as:

Threshold Ratio = (Current Reading – Lower Level) / (Upper Level – Lower Level)

The ratio is still defined when the feedback parameter goes outside the range defined by the two threshold levels – above the upper level the ratio is > 1 and below the lower, the ration is < 0.

Understanding the ratio will help to understand how several of the feedback screens work, and I will refer to it in the explanations.

1.6 Media Files

Many of the feedback screens rely on media files, either audio or image or video. For example there are several feedback screens that play soundtrack files. For reasons relating to copyright, MBTT software is supplied with only a very limited number of media resources – it's expected that each user will acquire or use their own media files.

1.6.1 Audio Files & File Conversion

Suitable audio files can be purchased easily from online vendors such as Amazon or iTunes. Usually these are supplied in .mp3 format. Some of the feedback screens require files in .wav format, and so you may need a way of converting your files.

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.

I have found that nature sounds work well in the context of neurofeedback – e.g. the sound of rain, or the dawn chorus, or a flowing stream. Music can also work, especially forms of music where it doesn't matter if the volume is variable. For example, you can search in your favourite music store for "music for sleep" or "music for relaxation".

1.6.2 Video Files

Some of the feedback screens involve a video player which is part of BioEra. This player has limitations – not every video file is suitable for use.

Personally I've used videos supplied with another software, called HEGStudio, which was created to work with one particular piece of neurofeedback hardware, but is available as a free download. Search for "download hegstudio" – at the time of writing it is available on a platform called SourceForge (designed for open-source software). These videos are simple animated flight videos – not very entertaining on their own level but useful in neurofeedback. Please note, they require a video codec to be installed on your computer, called "vp6". This codec is a software component that is available as a free download – just search on something like "download vp6 codec".

1.7 Audio Feedback, Latency and Buffer Length

In audio feedback, data is sent to the sound player in small packets. While the software is playing one packet of audio data, it is filling a "data buffer" with what will become the next packet of data, the calculation being based on the EEG feedback parameter.

Feedback latency was first mentioned in the main EEG Training User Guide. It is the small but inevitable gap in time between a physiological event (change in brain state), and the feedback of that event by the software. There is always some gap because the device has to measure the event, pass the data to the computer, and the software has to perform computations on the data.

In EEG training it is important to minimise latency.

In MBTT you can set a software parameter called "buffer duration" which affects latency. It is to do with the size of each packet of data sent to the sound player, or how long it takes the player to play that packet of audio data. The longer the buffer duration, the greater the latency. Therefore it needs to be set as low as possible to minimise latency – but if it's too low there will be resulting distortion of the sound.

Buffer duration can be set from the Set-up tab of the platform program. Clicking the button "Audio & Midi Options" will open up the BioEra application shown in figure 1.1 below.
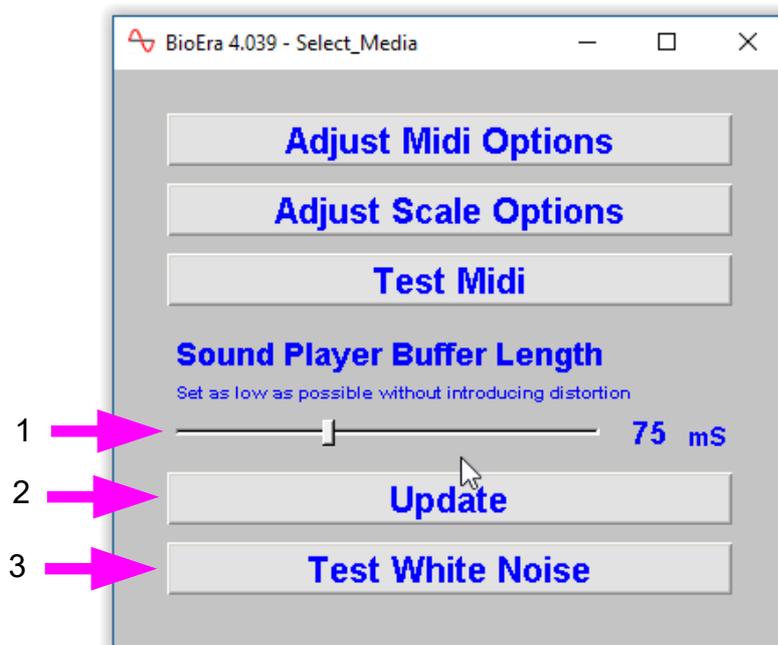

Figure 1.1 – BioEra Audio & Midi Options application

Click the button labelled 3 in figure 1.1 to generate a test sound. Adjust the slider control (1) to be as low as possible, without causing any clicks and splutters in the sound – please note you need to click the Update button (2) to propagate the slider setting to the sound player. In practice, since the real biofeedback applications are more computationally expensive than the test sound player, you'll need to set the buffer length a little longer.

The actual setting will depend on the speed / power of your computer.

1.8 Overview of the Guide to Feedback Screens

As stated earlier, the feedback screen options are presented as three lists: continuous, points-based and advanced. In this document there is a section for each of these three lists. The operation of each design is described in a sub-section. The screens are presented, broadly speaking, simplest first.

Finally there is a section on how to create your own feedback screens. This involves doing some graphical programming using BioEra, and hence is likely to be only relevant to committed and/or advanced users. The most simple feedback screens are presented in effect as templates (without password protection), which you can copy and edit.

2 Continuous Feedback Screens

This section describes screens based on continuous feedback. The operation of each screen is covered in individually.

2.1 Basic Continuous Graphical Feedback

This is the simplest of screens, it offers a basic graphical representation of the feedback parameter, and no audio feedback. Figure 2.1 below shows the screen. If training upwards (enhancing) the trainee should aim to have the trace go off the top of the chart, and if training down, the trace should disappear off the bottom.

The BioEra design for this feedback screen is not password protected and it can serve as a template for committed users who wish to develop their own feedback screens – see section 5 below.
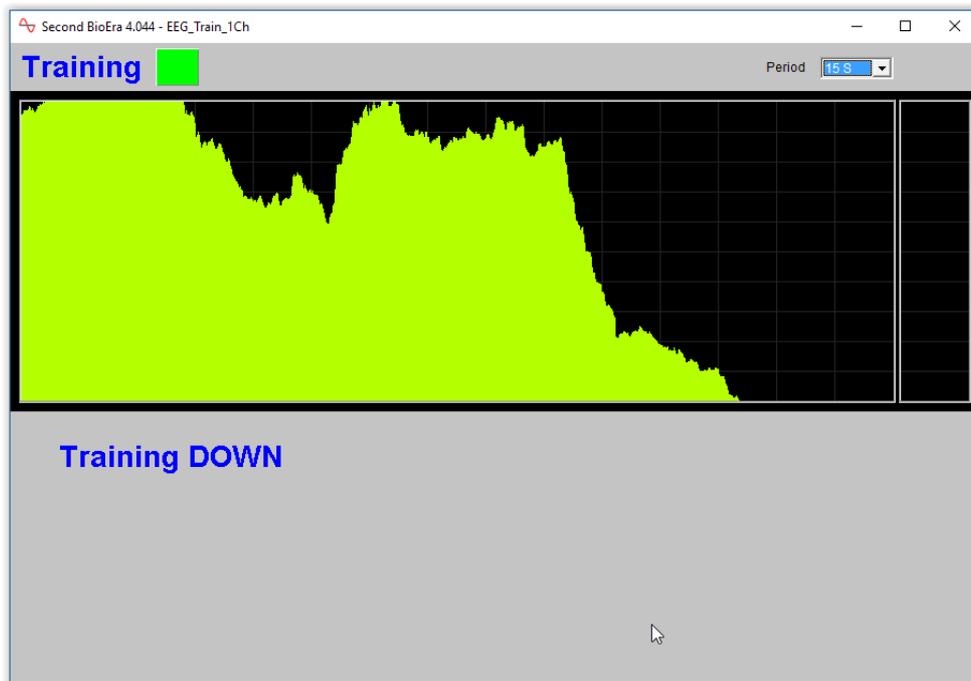

Figure 2.1 – Basic continuous graphical feedback

Displays

- Bar chart showing the main feedback parameter (at the right side of the screen). The scale is such that the very top of the chart is equivalent to the upper threshold level (main parameter threshold) and the very bottom is equivalent to the lower threshold level.

- Trend chart having the same scale as the bar chart, and showing the recent variation of the feedback parameter.

- Lamp display – turns green during a training period (i.e. when training is active) and then red at the end of a training period.

These elements are common to many of the feedback screens, and will not be listed for every screen.

Controls

- **Period** drop-down list – sets the time scale of the trend chart.

2.2 Basic Tone Feedback

Another simple feedback screen, this offers tone (audio) feedback, where the pitch and / or volume of the tone varies with the EEG parameter. Figure 2 below shows the user interface.
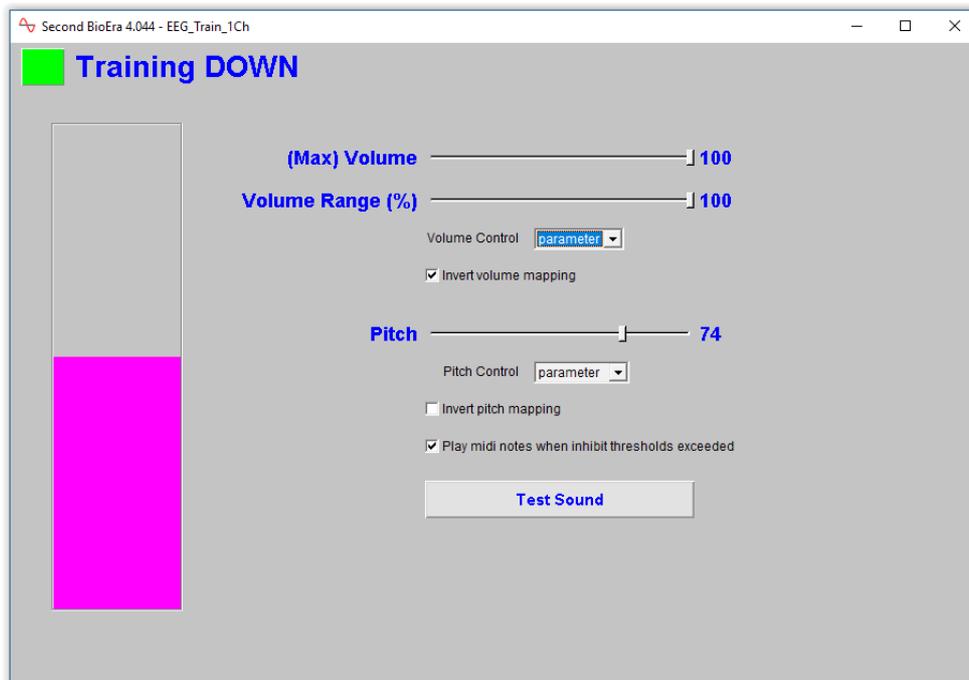

Figure 2.2 – Basic tone feedback screen

Displays

- Simple bar chart, scaled such that the very top of the chart is equivalent to the upper threshold level (main threshold) and the bottom, the lower threshold level. This display element is common to several of the feedback screens, and will usually not be listed separately.

Controls

- **Max Volume** slider – sets the upper limit to the range over which the volume varies.

- **Volume Range** slider – sets the percentage range over which the volume varies with the EEG feedback parameter. If set to 100%, the tone goes completely quiet when the feedback parameter drops out of the range set by the main threshold. At 25% the lowest volume is a quarter of the maximum volume.

- **Volume Control** drop-down list – sets whether volume should vary with the feedback parameter or stay constant. You can opt to restrict feedback to changes in pitch if you prefer.

- **Invert volume range** checkbox – when unchecked, the volume is high when the feedback parameter is high. Checking this control means that the volume goes low when the feedback parameter is high – i.e. the relationship between the two is flipped. Please note, the direction of training (up or down) is not taken into account.

- **Pitch** slider – sets the pitch of the tone, when the pitch is not following the feedback parameter (you can set it to be fixed using the following control).

- **Pitch Control** drop-down list – sets whether pitch should vary with the feedback parameter or stay constant. You can opt to restrict feedback to changes in volume if you prefer.

- **Invert pitch mapping** checkbox – when unchecked, the pitch is high when the feedback parameter is high. Checking this control means that the pitch goes low when the feedback parameter is high – i.e. the relationship between the two is flipped. Please note, the direction of training (up or down) is not taken into account.

- **Play midi notes when inhibit thresholds exceeded** (checkbox) – if your protocol uses inhibits, then you can opt to have audio warnings when the inhibit parameters exceed the upper threshold level. These notes repeat every second for as long as the threshold is exceeded.

- **Test Sound** toggle button – pressing this activates the sound outside of the training periods – this might be helpful in setting some of the controls such as the maximum volume.

2.3 Isochronic Beats

This feedback screen plays isochronic beats, which are distinct pulses of tone, at a regular frequency controllable by the user. They have potential to entrain the EEG, which means the EEG will tend to follow the frequency of the beats. So isochronic beats at 10 Hz (or 10 beats per second) could enhance alpha (10 Hz being in the middle of the alpha range).

Isochronic beats should not be confused with binaural beats – there is some similarity but isochronic beats do not require headphones.

There is some evidence that isochronic beats are more effective at entraining the brain than binaural beats.

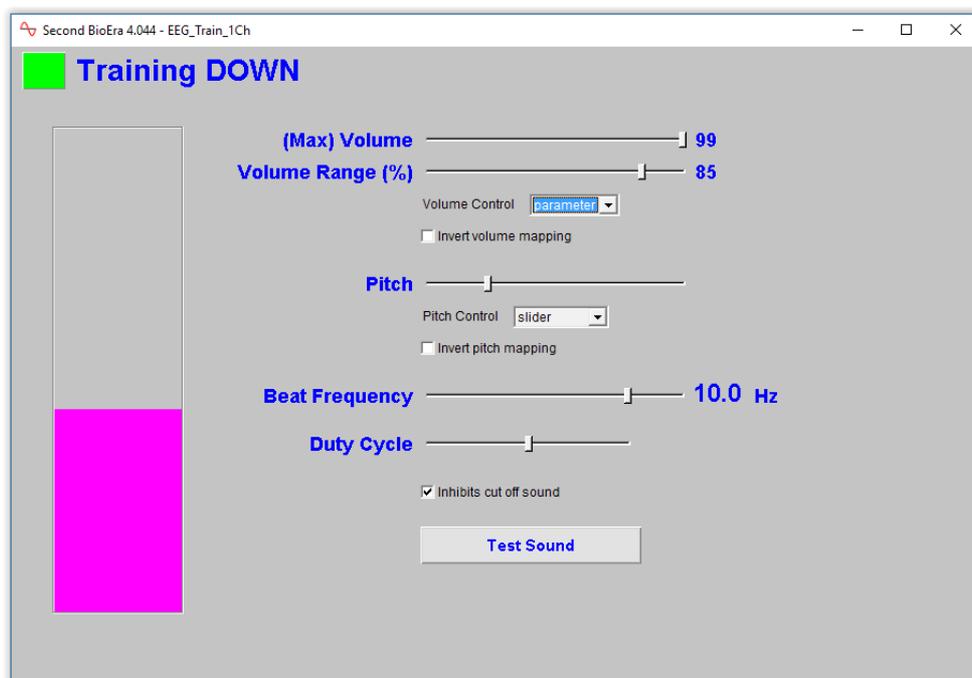Figure 2.3 below shows the screen.

Figure 2.3 – Isochronic beats feedback screen

<u>Controls</u>

- **Max Volume** slider – sets the upper limit to the range over which the volume varies.

- **Volume Range** slider – sets the percentage range over which the volume varies with the EEG feedback parameter. Equivalent to the basic tone feedback screen (section 2.2 above).

- **Volume Control** drop-down list – sets whether volume should vary with the feedback parameter or stay constant. You can opt to restrict feedback to changes in pitch if you prefer.

- **Invert volume range** checkbox – when unchecked, the volume is high when the feedback parameter is high. Checking this control means that the volume goes low when the feedback parameter is high – i.e. the relationship between the two is flipped. Please note, the direction of training (up or down) is not taken into account.

- **Pitch** slider – sets the pitch of the tone, when the pitch is not following the feedback parameter (you can set it to be fixed using the following control).

- **Pitch Control** drop-down list – sets whether pitch should vary with the feedback parameter or stay constant. You can opt to restrict feedback to changes in volume if you prefer.

- **Invert pitch mapping** checkbox – when unchecked, the pitch is high when the feedback parameter is high. Checking this control means that the pitch goes low when the feedback parameter is high – i.e. the relationship between the two is flipped. Please note, the direction of training (up or down) is not taken into account.

- **Beat Frequency** slider – the scale is not uniform: at lower frequencies the step is 0.5Hz and 1.0 Hz at higher frequencies. You can also set a beat frequency of 7.83 Hz which is the Schumann resonance frequency. Using this frequency may have a particular effect on the brain.

- **Duty Cycle** slider – this sets the relative duration of each pulse of sound. A low duty cycle will give a short, clipped sound, with more silence than sound. At the higher end of the scale the pulses begin to merge into one another (though the beat is still discernible).

- **Test Sound** toggle button – pressing this activates the sound outside of the training periods – this might be helpful in setting some of the controls such as the maximum volume.

2.4 Binaural Beats

This screen is very similar to the isochronic beats design described in the previous section, but uses binaural beats instead. Binaural beats are an audio technology also believed to influence brain state, though there is some doubt as to whether they actually entrain the EEG to a significant degree.

In any case, there is a beat frequency which can be set my the user. However there is no equivalent of "duty cycle".

Binaural beats require headphones, or at least stereo speakers clearly on opposite sides of the head.

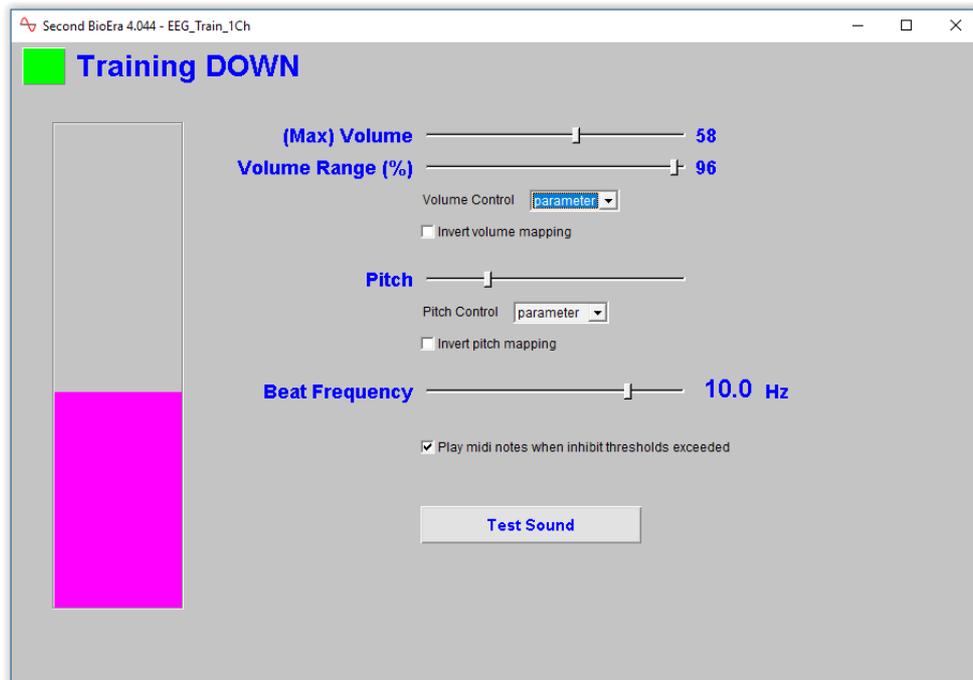Figure 2.4 below shows the screen and its controls.

Figure 2.4 – Binaural beats feedback screen

Controls

- **Max Volume** slider – sets the upper limit to the range over which the volume varies.

- **Volume Range** slider – sets the percentage range over which the volume varies with the EEG feedback parameter. Equivalent to the basic tone feedback screen (section 2.2 above).

- **Volume Control** drop-down list – sets whether volume should vary with the feedback parameter or stay constant. You can opt to restrict feedback to changes in pitch if you prefer.

- **Invert volume range** checkbox – when unchecked, the volume is high when the feedback parameter is high. Checking this control means that the volume goes low when the feedback parameter is high – i.e. the relationship between the two is flipped. Please note, the direction of training (up or down) is not taken into account.

- **Pitch** slider – sets the pitch of the tone, when the pitch is not following the feedback parameter (you can set it to be fixed using the following control).

- **Pitch Control** drop-down list – sets whether pitch should vary with the feedback parameter or stay constant. You can opt to restrict feedback to changes in volume if you prefer.

- **Invert pitch mapping** checkbox – when unchecked, the pitch is high when the feedback parameter is high. Checking this control means that the pitch goes low when the feedback parameter is high – i.e. the relationship between the two is flipped. Please note, the direction of training (up or down) is not taken into account.

- **Beat Frequency** slider – as in the isochronic beats design, the scale is not uniform, and can be set to the Schumann frequency of 7.83.

- **Play midi notes when inhibit thresholds exceeded** checkbox – if your protocol uses inhibits, then you can opt to have audio warnings when the inhibit parameters exceed the upper threshold level. These notes repeat every second for as long as the threshold is

exceeded.

- **Test Sound** toggle button – pressing this activates the sound outside of the training periods – this might be helpful in setting some of the controls such as the maximum volume.

2.5 Soundtrack (Basic)

This is another (predominantly) an audio feedback screen. Although it contains the standard parameter trend display, it is intended mainly for eyes-closed training, like the other soundtrack designs listed later. It plays a sound file at a volume which varies with the EEG feedback parameter. The user can select the file, and it is played in a loop (meaning when it finishes it starts over again).

The sound can be either aversive feedback or reward feedback (see section 1.3 above).

I personally use this screen when training myself, more than any other, and I have found that nature sounds work very well. My go-to track is a recorded rain storm with thunder in the background, which I use as aversive feedback (i.e. it plays when I lose my desired brain state). Sometimes I use a reward sound and I select a dawn chorus soundtrack. (I bought both these tracks from an online retailer – see section 1.6 above.)

The soundtrack file must be in .wav format. See my comments in section 1.6.1 above.

Figure 2.5 below shows this screen.

Figure 2.5 – Basic soundtrack feedback screen

Controls

- **Max Volume** slider – sets the upper limit to the range over which the volume varies.
- **Volume Range** slider – sets the percentage range over which the volume varies with the EEG feedback parameter. If set to 100%, the tone goes completely quiet when the feedback parameter drops out of the range set by the main threshold. At 25% the lowest volume is a quarter of the maximum volume.

- **Invert volume range** checkbox – when unchecked, the volume is high when the feedback parameter is high. Checking this control means that the volume goes low when the feedback parameter is high – i.e. the relationship between the two is flipped. Please note, the direction of training (up or down) is not taken into account, however it will be one of two factors which dictate your choice of setting (the other factor being whether you want reward feedback or aversive feedback).

- **Select Audio File** button – allows the user to select the audio file to be used. The last audio file used is remembered by this screen.

- **Test Sound** toggle button – allows the user to play the sound outside of a training period , in order to check the right sound file is selected and working, and that the volume setting is appropriate.

2.6 Soundtrack With Inhibits Feedback

This feedback screen works like the basic soundtrack screen (previous section) but offers additional feedback: if either of the inhibit thresholds are exceeded then midi notes are played. As with the basic soundtrack screen, the audio files must be in .wav format.
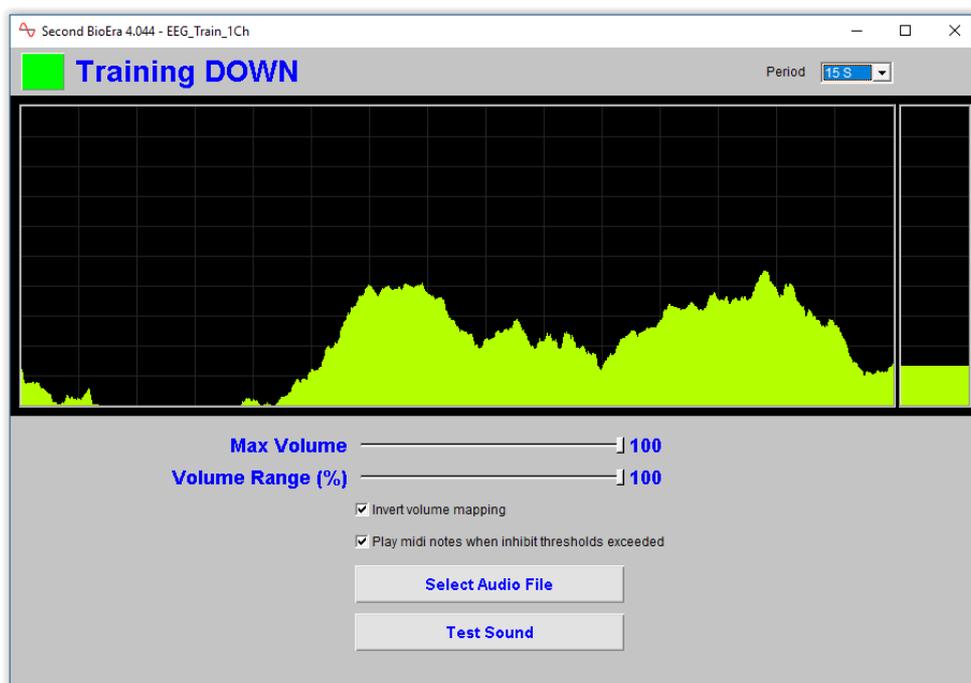

Figure 2.6 – Soundtrack with inhibits feedback screen

Controls

The controls are the same as for the basic soundtrack screen, but with one extra control:

- **Play midi notes when inhibit thresholds exceeded** checkbox – this turns on or off the inhibit audio feedback.

2.7 Soundtrack – Playlist

This feedback screen also plays soundtrack files as the medium of feedback, but there are significant differences from the last two screens.

It plays a set of files in sequence, rather than just one in a loop. The audio files are loaded from a single folder, and the files must have names beginning with numbers, which define the order of play – e.g. "1.mp3", "2.mp3", etc. (The user can select the source folder.)

The design intent is to offer a listening concentration exercise. I personally use this screen to work with verbal material, i.e. drawn from audio books.

Feedback is aversive: it takes the form of distortion of the sound making listening harder.

There are two modes of feedback: (i) white noise (hiss) interference sound is played at a volume that varies with the feedback parameter – getting louder the further away from the target state the signal goes. If you're training your parameter up, then the hiss is louder the lower the parameter. If training down, the hiss is louder the higher the parameter. (ii) the volume of the soundtrack itself can change with the feedback parameter, getting quieter the further away from target the signal drifts.

The sound files can be in either .wav or .mp3 format, though the user must first select which.

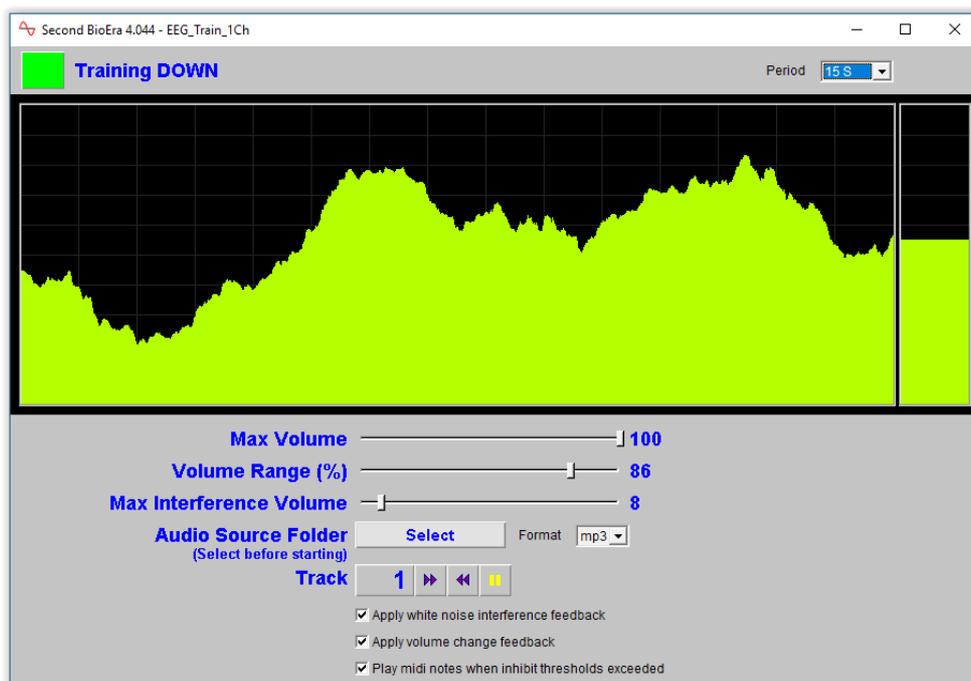Figure 2.7 below shows the screen and controls.

Figure 2.7 – Soundtrack (playlist) feedback screen

Controls

- **Max Volume** slider – sets the upper limit to the range over which the soundtrack volume varies.

- **Volume Range** slider – sets the percentage range over which the volume varies with the EEG feedback parameter. If set to 100%, the tone goes completely quiet when the feedback

parameter drops out of the range set by the main threshold. At 25% the lowest volume is a quarter of the maximum volume.

- **Max Interference Volume** slider – sets the upper limit to the range over which the interference (hiss) volume varies.

- **Select Audio Source** button – opens a dialog to select the folder containing the sound files to be used

- Track change buttons: forward, backward – these buttons move to the next or previous track in the sequence. The numeric display shows the current track number.

- **Pause** button – pauses and unpauses the sound.

- **Use white noise interference** checkbox – when this is unchecked there is no white noise played and the volume change is the only medium of feedback.

- **Apply volume change feedback** checkbox – when this is unchecked, the soundtrack plays at an unchanging volume and the only medium of feedback is the variable white noise.

- **Play midi notes when inhibits exceed thresholds** checkbox – turns on or off audio feedback of inhibit parameters.

2.8 Image Brightness

This screen displays an image, which is initially black, but increases in brightness at a rate determined by the feedback parameter. As the parameter moves towards the target state, the brightness increases the faster. If you're training down, then the brightness increases faster when the parameter is lower, and if training up, then the opposite.

The brightness can also decrease again, if the parameter moves out of the threshold range, i.e. if training down, brightness decreases when the parameter moves above the upper threshold, and if training up, brightness decreases when the parameter moves below the lower threshold.

When the image reaches full brightness, a new image is loaded, and starts off fully dark again.

The images used are read from a folder which the user can select.

A small number of image files are included with MBTT, enough to demonstrate the use of this screen, but I anticipate users will want to use their own images.

For optimal performance, it may be worthwhile to resample any large image files to a lower resolution. A width of about 900 pixels will fit the feedback screen in its default size (which can of course be changed).
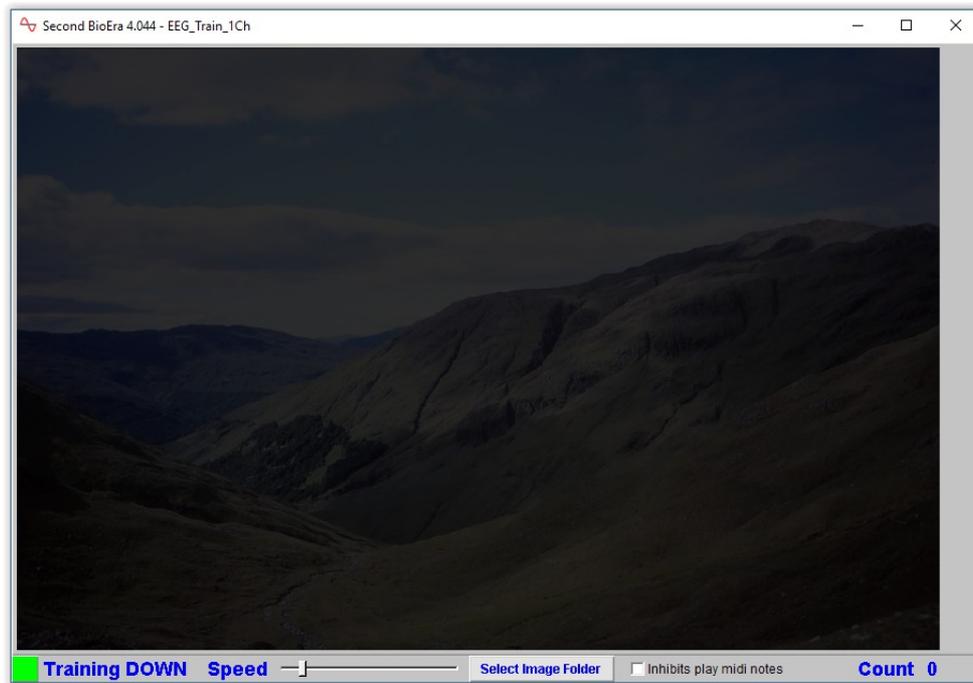
Figure 2.8 below shows the screen.

Figure 2.8 – Image brightness feedback screen

<u>Controls</u>

- **Speed** slider – sets the maximum rate of increase of brightness. Having this set further to the right means the trainee can progress faster through the images.

- **Select Image Folder** button – opens a dialog to select the source of image files.

- **Inhibits play midi notes** checkbox – when checked, midi notes are played when either inhibit parameter exceeds the upper threshold limit.

2.9 Video Speed Feedback

This feedback screen plays a video, where the play speed varies with the feedback parameter.

It's designed for a particular kind of video: simple animated "flight" or movement videos. See my comments in section 1.6.2 above.

As you'd expect, the main threshold limits define the range for the speed variation. Speed is maximum at and beyond one, while the video stops at the other limit.

The video can optionally move backwards when the feedback parameter drops below the threshold range.

If you're training up, maximum speed is at the upper threshold, the video stops at the lower, and moves backwards below the lower (again backward speed is set by the feedback parameter). If training down, it's the other way around.

You can also play a soundtrack file with variable volume – volume changes parallel video speed changes. For example you can use an aircraft engine sound with flight videos. You can find audio samples online e.g. https://www.freespecialeffects.co.uk.

<u>Video Player Reliability Issues</u>

This design is possible because BioEra has an internal video player, which is based on Microsoft technology. However, this video player is not reliable, especially in Windows 10, for reasons outside my control (essentially, it seems the video player is rather old technology which Microsoft no longer supports very well). In my experience reliability is a quirk of the individual computer.

Another way is employ video feedback is to use an external video player, and using the feedback screen described in the next section.
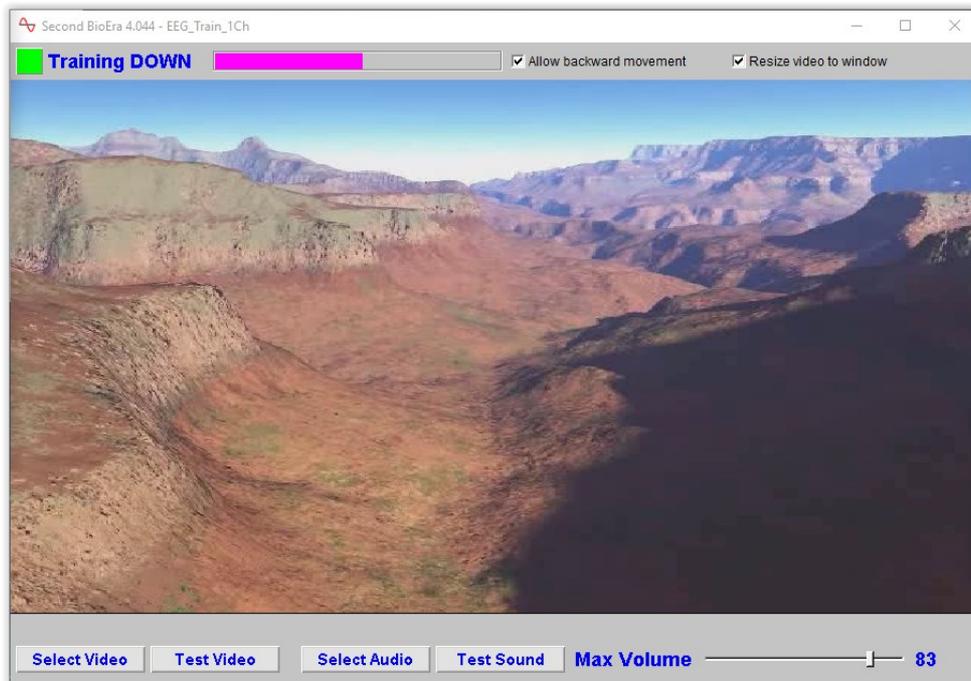

Figure 2.9 – Video speed feedback screen

<u>Controls</u>

- **Allow backward movement** checkbox – when unchecked the video can only move forwards.

- **Resize video to screen** checkbox – when checked, the video is resized to fit to the screen. When unchecked the video keeps its original size, and this may help to make the video player more reliable. Please note the **application must be restarted** for changes to take effect.

- **Select Video** button – opens a dialog to select a video file.

- **Test Video** button – allows you to test if the selected video plays.

- **Select Audio** button – opens a dialog to select the audio soundtrack.

- **Test Sound** button – tests the selected sound file.

- **Max Volume** slider – sets the maximum volume of the soundtrack.

2.10   BxShadowEra With Audio Interference

In section 2.9 I pointed out that BioEra's internal video player is not always reliable, for reasons outside of the control of both myself and the developer of BioEra. An alternative means of offering video feedback is to use an external video or DVD player (e.g. VLC media player) in combination with a third-party product called BxShadowEra. This software creates a window with variable opacity, known as the "shadow" window. The idea is to position this shadow window over the top of the video player. The shadow partially obscures (in effect, darkens) the video, except when the EEG feedback parameter is in its target state, in which case the opacity is zero and the video view is unimpeded.

BxShadowEra is able to communicate with the BioEra training app in real time so that in effect the feedback parameter controls the opacity of the shadow window. Opacity can vary continuously between 0 and 100% if desired – the user can set the precise range.

In addition to varying the shadow opacity, you can optionally use white noise (hiss) interference, just as described in the soundtrack (playlist) feedback screen (see section 2.7 above). To summarise, the software plays white noise or hiss (which interferes with your video's audio) at a variable volume – the further from target the EEG feedback parameter is, the louder the hiss.

Besides using BxShadowEra in conjunction with a video player, you could use this screen with any other software of your choosing, such as a video game, or a reader application. For example, you can make the training session a test of concentration on reading, and have the shadow window obscure a page of text, e.g. in Amazon's kindle reader app.

BxShadowEra is not included with MBTT and must be purchased separately.

This feedback screen can be used without BxShadowEra – you can simply employ the white noise feedback

Figure 2.10 below shows the BioEra app's feedback screen. BxShadowEra has its own control window (see section 2.10.1 below).
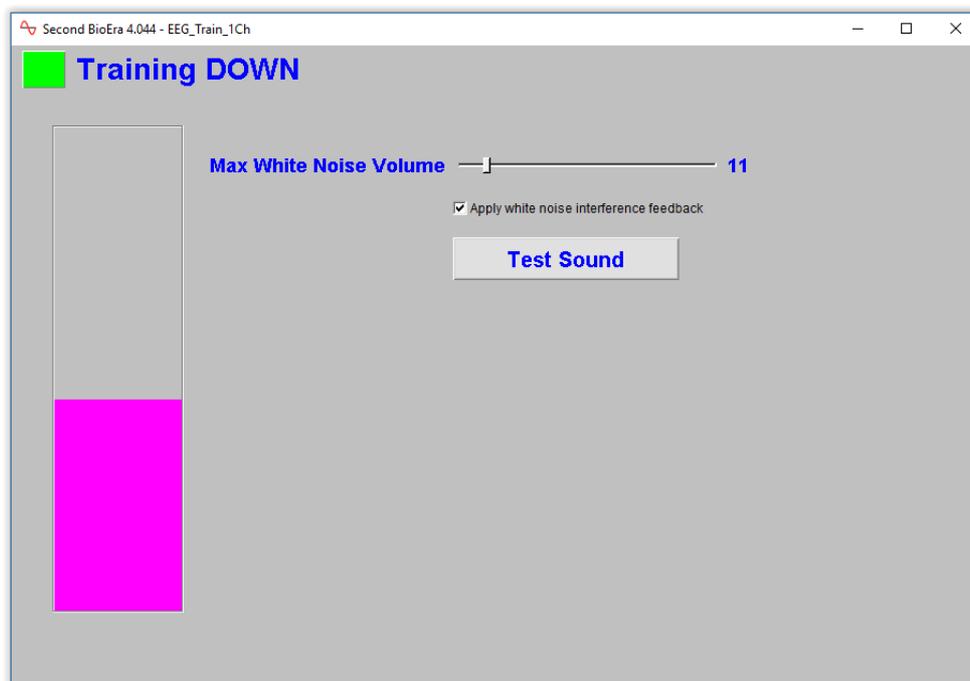

Figure 2.10 – BxShadowEra feedback screen

<u>Controls</u>

- **Max White Noise Volume** slider – sets the upper limit of the range of volume variation of the hiss. Note this does not affect the external video player's volume.

- **Apply white noise interference feedback** checkbox – this turns on or off the use of white noise. Unchecked means you rely on the shadow window only for feedback.

- **Test Sound** button – tests the white noise outside of the training context, so you can set the maximum volume to your liking.

2.10.1   Operating BxShadowEra Software

Figure 2.10.1 below shows the user interface for BxShadowEra.
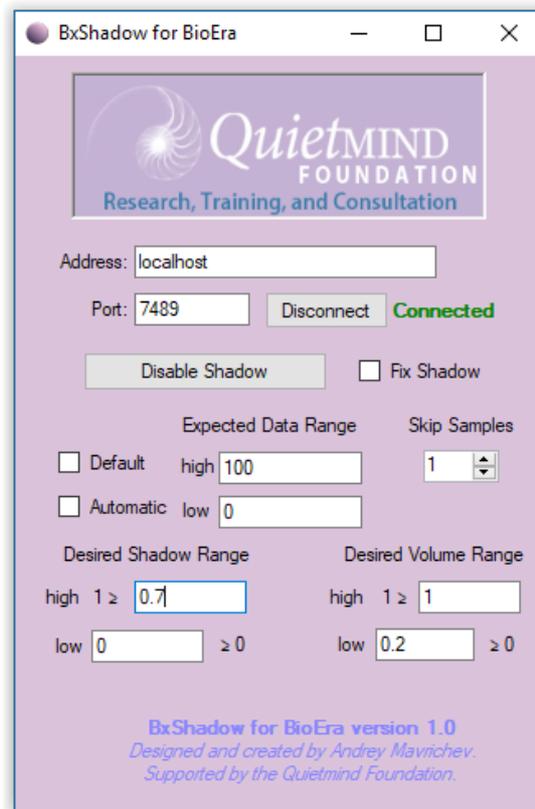

Figure 2.10.1 – BxShadowEra application interface

Steps required for operating the BxShadowEra software are as follows:

1. Launch the BxShadowEra application.

2. With the BioEra EEG training app running (but not in a training period) press the button "Connect" – this establishes the communication between the two programs. If the link-up happens as it should, you should see the "connected" message (as in figure 2.10.1) and the Connect button then displays "Disconnect".

3. Also click the button "Enable Shadow" to create the shadow window. Bear in mind two things about this window: first, if the opacity goes to zero, you can't see it! And second, you cannot click on buttons etc. that are behind the shadow. I suggest you position it and size it carefully.

4. The MBTT training application sends a number between 0 and 100 to set the "brightness" or opacity of the shadow window. Make sure to have 0 and 100 entered in the expected data range, as you see in figure 2.10.1.

5. Set the desired shadow range as you see fit. A low of zero gives maximum transparency of the shadow, hence maximum "brightness" – I expect most users will use this setting. At the other extreme, a high of 1 gives a completely opaque shadow, which you may not want. As you see in the figure I've used 0.7 and that gives a fairly dark shadow but still with some transparency, so the video image can still be made out.

2.11   Continuous Midi Feedback

This screen is designed for audio feedback in the form of continuous midi sound.

Midi sound can take the form of distinct or discrete notes such as piano notes (e.g. see section 3.2 below) or, using different "instruments", it can be a continuous sound with no breaks between notes. For example selecting "strings" as the instrument serves this end.

Feedback can be conveyed through pitch and volume changes, rather like the basic tone feedback screen (section 2.2 above).

In this design, volume can vary continuously, but pitch is restricted to a set of particular musical notes which together make up a (harmonious) chord. There are a total of five notes.

Suppose you're training your parameter up (enhancing it). As the parameter crosses the lower threshold level, the first note comes in. As the parameter increases further, more notes are added, until all five sound at the upper threshold level.

Additionally, as the parameter increases the volume of the sound likewise increases.

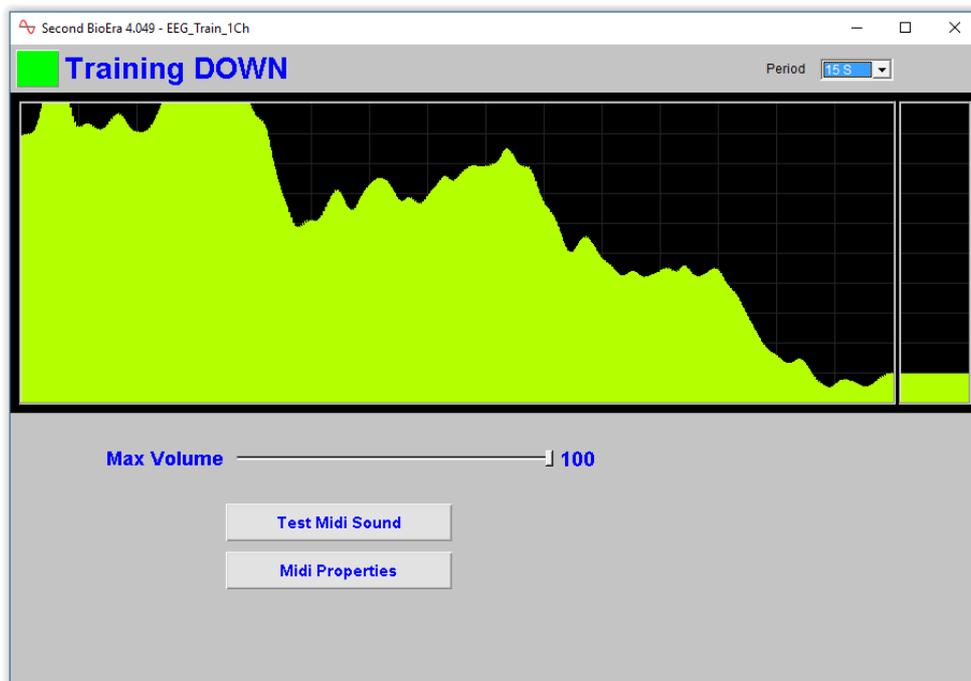Figure 2.11 below shows this screen.

Figure 2.11 – Continuous midi feedback screen

Controls

- **Max Volume** slider – sets the upper limit to the range over which the volume varies.

- **Test Midi Sound** button – pressing this activates the sound outside of the training periods – this might be helpful in setting e.g. maximum volume. Please note, the sound will still be based on the feedback parameter, which if out of range may result in no sound.

- **Midi Properties** button – opens a dialog allowing you set properties of the midi, most notably the instrument (strings, etc.). Please note, you need to select an instrument which produces continuous sound.

3 Points-based Feedback Screens

This section describes the operation of each of the points-based feedback screens individually. In all cases a point is scored when the main feedback parameter either goes above its upper threshold limit (in the case of training up) or falls below its lower limit (when training down) – so long as neither inhibit parameter (if in use) is above its upper threshold limit.

3.1 Basic Points

This is the simplest of the points-based screens. It plays a sound when a point is scored, and also a lamp display flashes green briefly.

By default the sound is a bell-chime, but you can select your own audio file if you prefer. For example, if you wanted the sound to be a warning rather than a reward, you could select a more discordant sound (and the training objective would be to keep the points tally as low as possible).

All of the points-based screens play a sound for each point, in the same way as this screen, and hence will not be explicitly mentioned again. In each case the sound file is independently selectable.

The BioEra design for this feedback screen is not password protected and it can serve as a template for committed users who wish to develop their own feedback screens – see section 5 below.

Figure 3.1 below shows this screen and its controls.

Figure 3.1 – Basic points feedback screen

Displays

- Lamp which changes from red to green for the duration of each training period.
- Lamp which flashes briefly for each point scored.
- Points tally numeric display.

The above displays are present in some form, in virtually all of the points-based screens, and will not be listed again.

Controls

- **Volume** slider – sets the volume of the sound played for each point.

- **Select Audio File** button – opens a dialog to select a different audio file to be played for each point. The selection is remembered for subsequent training sessions.

- **Test Sound** button – allows you to test how a point-score sounds outside of training, so that you can e.g. set the volume to your liking.

3.2 Midi Notes

This screen is similar to the basic points screen, except that instead of playing a sound file, a midi note is played. To add some interest, the midi notes ascend in pitch with each successive point. When the highest note is reached, the pitch is reset back to the beginning note.
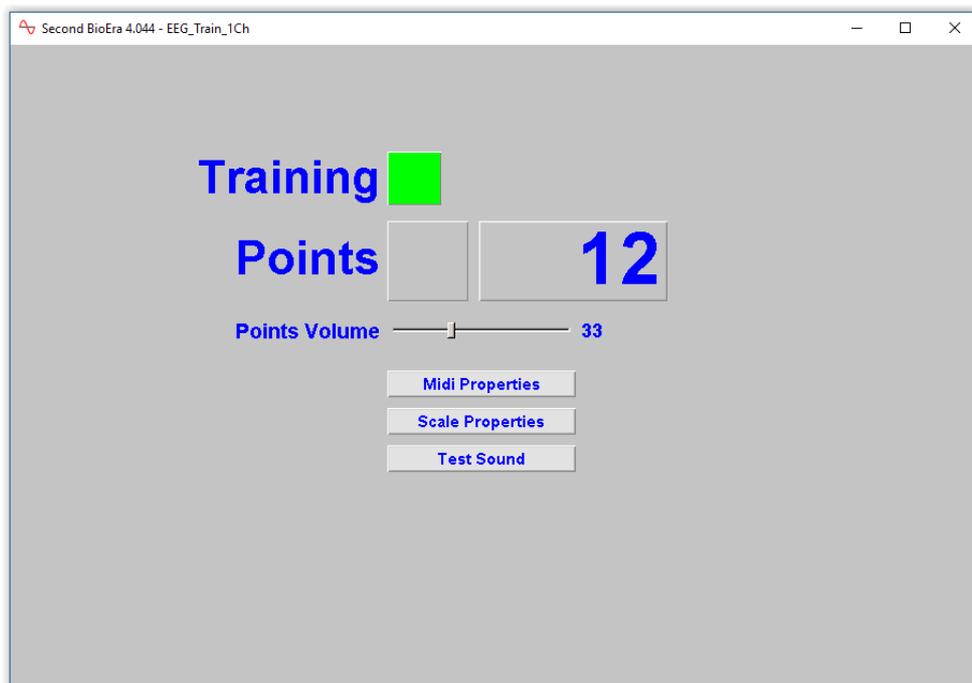
Figure 3.2 shows the screen.

Figure 3.2 – Midi notes feedback screen

Controls

- **Midi Properties** button – opens a dialog allowing you set properties of the midi, most notably the instrument (piano, etc.)

- **Scale Properties** button – opens a dialog allowing you to specify properties of the midi scale, e.g. "pentatonic major".

- **Test Sound** button – allows you to test the sound of the midi player as you've configured it – useful if you make changes e.g. to the instrument.

3.3 3D Spectrum

Besides playing a sound for each point (in the same way as the basic points screen) this screen shows a 3D spectrum display. The latter shows successive spectral analyses (Fourier analyses) with the most recent at the bottom or "front".

The 3D spectrum display does not relate to points, and in fact I would say it is not particularly useful as feedback, but can be interesting to watch.
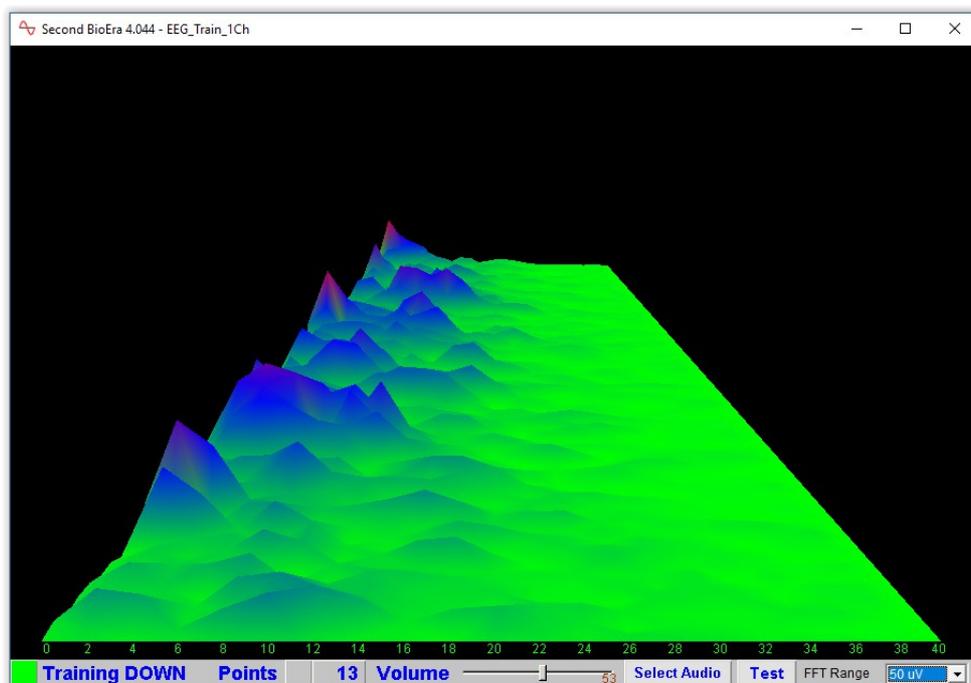

Figure 3.3 – 3D Spectrum feedback screen

Displays

- 3D spectrum display – as described above.

Controls

In addition to those controls described for the basic points-based design,

- **FFT Range** drop-down list – sets the "vertical" range of the 3D spectrum display – how tall the peaks reach.

3.4 Colours Progression

In this screen most of the space is taken up by a coloured background. Each time a point is scored, the colour changes, working through the spectrum from red to violet in steps. There are sixteen distinct colours. Outside of training periods the display is black.

Figure 3.4 shows the screen below.

Figure 3.4 – Colours progression feedback screen

Displays

- Colour panel as described.

Controls

- The controls are the same as for the basic points screen (section 3.1 above).

3.5 Image Brightness

This screen displays an image, which is initially black, but with each successive point scored, brightens. When the image reaches full brightness, a new image is loaded, and starts off fully dark again. There is a distinct number of steps between the initial black and full brightness, and this number of steps can be set by the user.

The images used are read from a folder which the user can select.

A small number of image files are included with MBTT, enough to demonstrate the use of this screen, but I anticipate users will want to use their own images.

For optimal performance, it may be worthwhile to resample any large image files to a lower resolution. A width of about 900 pixels will fit the feedback screen in its default size (which can of course be changed).
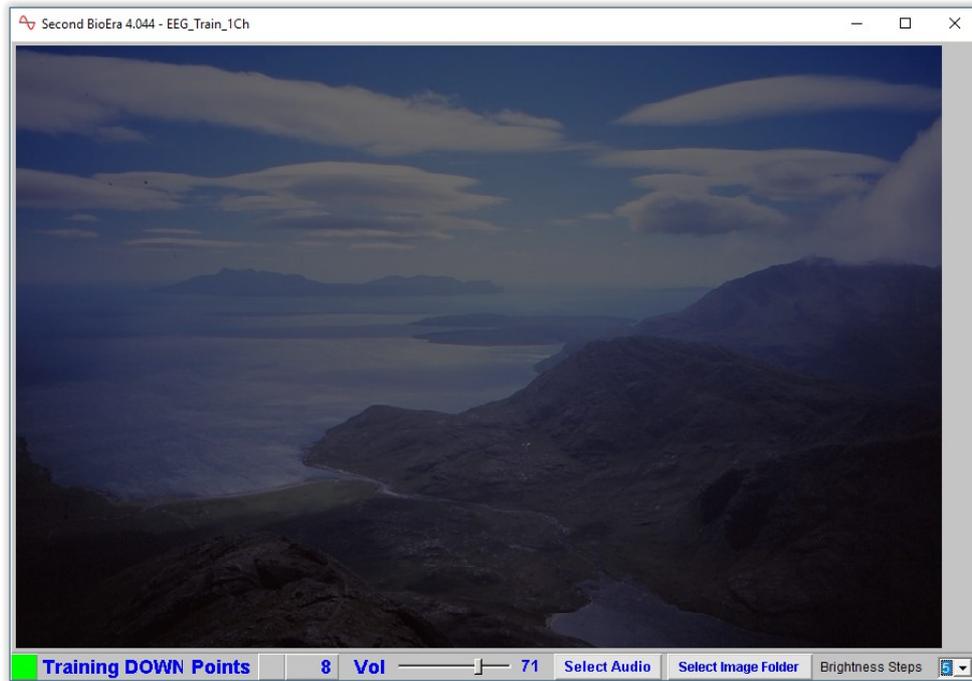
Figure 3.5 below shows the screen.

Figure 3.5 – Image brightness (points-based) feedback screen

Displays

In addition to the elements listed for the basic points screen.

Controls

In addition to those listed for the basic points screen:

- **Select Image Folder** button – opens a dialog to select a folder from which the software will load images. The images will be loaded from this folder in alphanumeric order (based on file name). The selection is remembered for subsequent training sessions.

3.6 Pacman Game

In the pacman game, a figure (pacman) moves around a maze eating pac-dots. The pacman moves forward only when a point is scored, and he eats approximately one dot per point (though not precisely one).
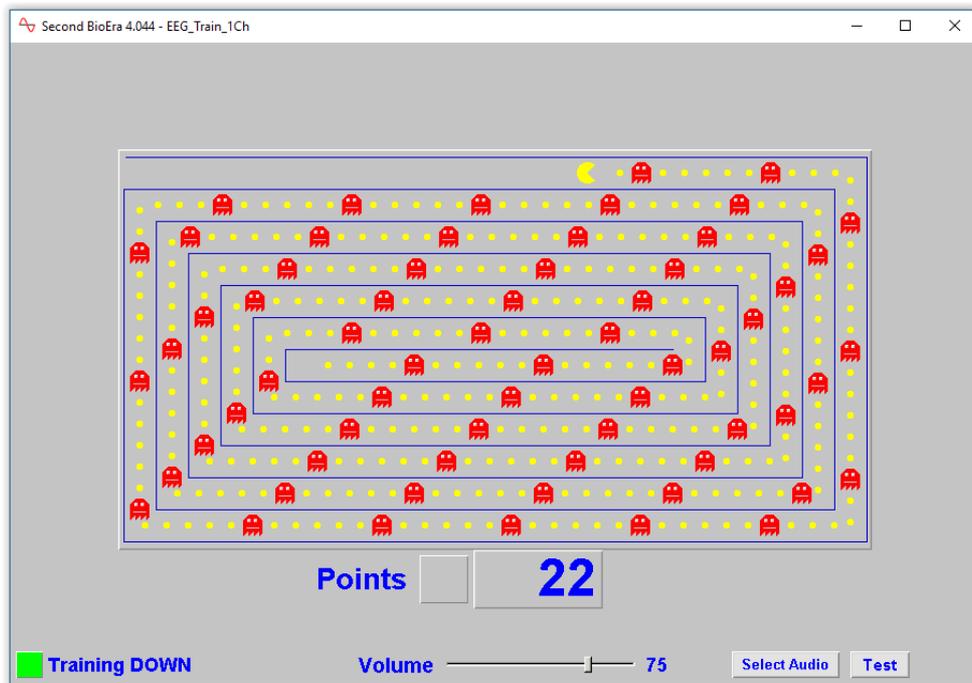
Figure 3.6 shows the screen.

Figure 3.6 – Pacman game feedback screen

Controls

The screen has the same controls as for the basic points screen.

4 Advanced Feedback Screens

Advanced feedback screens are more complex, and may have elements of both continuous and discrete feedback.

Section 2 listed some screens offering soundtrack feedback. Some of the advanced screens extend this concept by using two soundtracks.

4.1 Dual Soundtrack, Continuous Feedback

This design works like the basic soundtrack screen listed in section 2.5 – it plays a primary soundtrack whose volume varies continuously based on the main feedback parameter – volume varying as the EEG feedback parameter varies between the two levels of the main threshold. In addition, a secondary soundtrack is played when the feedback parameter moves outside of the range defined by the two threshold levels. The secondary soundtrack also varies proportionately (continuously), based on a range defined by the two threshold levels.

Figure 4.1 below shows this screen.

You can think of the primary feedback as a reward sound and the secondary soundtrack as a warning sound.

The precise behaviour depends on whether you're training up or down. If you're training up, then the primary soundtrack increases in volume as the feedback parameter goes from the lower threshold level (at which the volume is zero) to the upper (at which the volume is maximum). If the feedback parameter drops below the lower threshold level, the secondary soundtrack comes in, at a volume that increases the lower the parameter falls, reaching a maximum when the threshold ratio is negative one – please see section 1.5 above for a description of the threshold ratio).

If you're training down, the relationship is switched. The primary (reward) soundtrack plays when the feedback is below the upper threshold limit, with volume zero at the upper level, and increasing to a maximum at the lower threshold level. The secondary soundtrack plays when the feedback parameter rises above the upper threshold level.
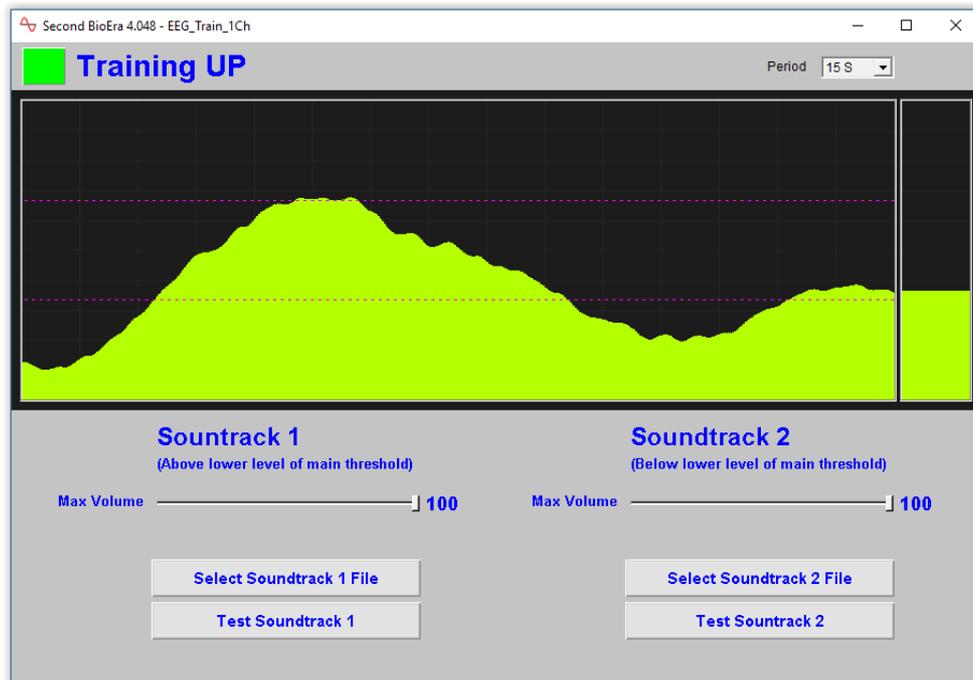
Figure 4.1 – Dual soundtrack feedback screen 3

Displays

- The main parameter trend is slightly different than in other screens – it has a wider range, showing the upper and lower limits as dotted lines.

Controls

- **Soundtrack 1 Max Volume** slider – sets the upper limit of the range of variation in volume of the reward soundtrack.

- **Select Soundtrack 1 Audio File** button – opens a dialog to select the audio file for the reward soundtrack.

- **Test Soundtrack 1 Sound** button – tests the reward sound outside of training periods, so you can adjust volume etc.

The following three controls are equivalent to the above three, but apply to the secondary soundtrack.

- **Soundtrack 2 Max Volume** slider

- **Select Soundtrack 2 File** button

- **Test Soundtrack 2** button.

4.2 Dual Soundtrack 5 – Both Tracks Based On Main Threshold, With Stop-Go Feedback

This feedback screen is relatively simple in its operation – it plays one soundtrack, the primary track, when the feedback parameter goes above the upper threshold limit, and a secondary soundtrack when the feedback parameter goes below the lower limit. Both soundtracks are either on or off, and there is no variation of volume with the feedback parameter. When the parameter is between the two threshold limits, no sound plays.

This feedback screen does not take account of training direction (up or down).

There is an option to cut off the primary soundtrack when either of the inhibit parameters crosses its upper threshold.
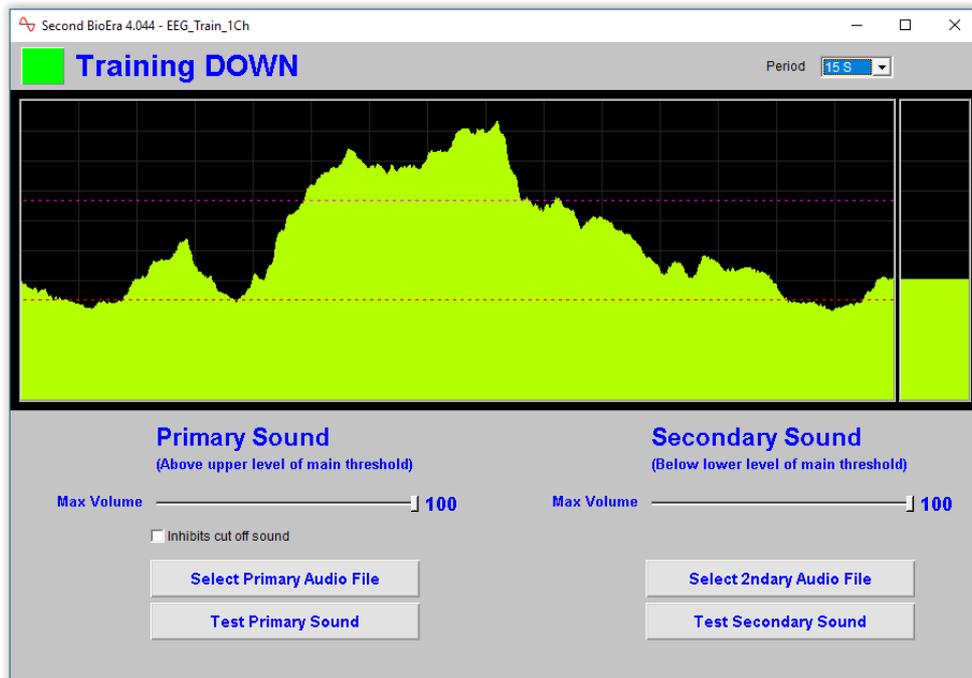
Figure 4.5 below shows the feedback screen.

Figure 4.5 – Dual soundtrack feedback screen 5

The controls for this screen are the same as for the previous (see section 4.4 above).

4.3 Video With Stop-Go Feedback

This feedback screen contains a video player which stops playing when the main feedback parameter goes out of range. If you're training up, it stops when the feedback parameter drops below the lower threshold level, and if you're training down, it stops when the parameter goes above the upper level.

In addition, the video stops if either inhibit parameter exceeds its upper level.

Otherwise the video plays normally.

In section 2.9 above I explained that BioEra's internal video player is not always reliable, especially in Windows 10.

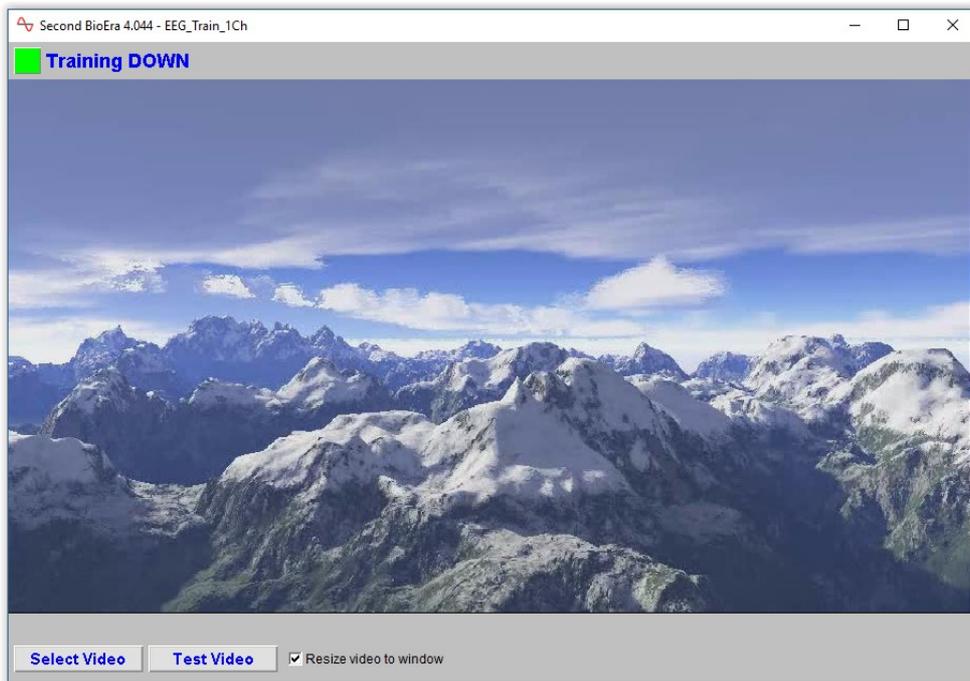Figure 4.6 below shows this feedback screen.

Figure 4.6 – Stop-go video feedback screen

Controls

- **Select Video** button – opens a dialog to select the video file.
- **Test Video** button – tests the selected video outside of training periods.
- **Resize video to window** checkbox – when unchecked the video is played in its native size, which may sometimes be more reliable. Please note you need to **restart the EEG training application for changes to take effect**.

5 Creating Your Own Feedback Screens (Advanced Users)

It's possible to create your own feedback screens. To do this you'll need to create your own BioEra design file, and you'll need to be competent in the graphical style of programming used in BioEra. The technical challenges are such that I anticipate most users will not avail themselves of this possibility.

In this guide I outline the steps necessary to create and use a feedback screen but I do not discuss how to program in BioEra (for that I suggest you start with the BioEra online manual – http://www.proatech.com/be/manual.html)

All the feedback screen files are located in a single folder, viz.

> [BioEra Root]\design\YBF\EEGTrain\FeedbackScreens

(For details of what "BioEra Root" means, please see the Installation & Set-up Guide.)

Each feedback screen has two files associated with it: a text file and a BioEra design file. The Platform application reads information about the feedback screen from the text file, while the design file is loaded as a nested design by the BioEra training application. Creating your own feedback screen is a matter of copying (the two files for) an existing feedback screen, which serves as a template, and then editing the files.

To create a feedback screen, carry out the following steps (working in the above folder containing feedback screens).

1. Decide which screen to use for your template – whichever one is closer to your design intent – either the basic continuous screen or the basic points screen. (These designs are not password-protected, while all the other feedback screen designs are, so can't be used as templates.)

2. Copy the text file template – either P_01_Basic.txt (points-based) or C_01_Basic.txt (continuous). You can choose the new filename.

3. Copy the BioEra design file – either P_01_Basic.bpd or C_01_Basic.bpd.

4. Edit the contents of your new text file, the contents of which are something like this:

> name YOUR NEW NAME HERE
> type points
> design YOUR_NEW_FILENAME_HERE.bpd
> description YOUR TEXT HERE

   The most essential thing is to add the filename of your new BioEra design on the third line.

   The name is what gets listed in the platform program.

   The type dictates which tab your design is listed under in the platform program – it should be one of: 'continuous', 'points' or 'special', and should not be anything else.

5. Finally, edit your BioEra design by loading it into BioEra in designer mode. Figure 5.1 below shows BioEra's designer screen. This of course is the major work of the process.

When editing your design, there are two constraints to bear in mind:

• The nested design inputs cannot be altered, otherwise your design will not connect properly to the main BioEra training design. You don't need to make use of any input.
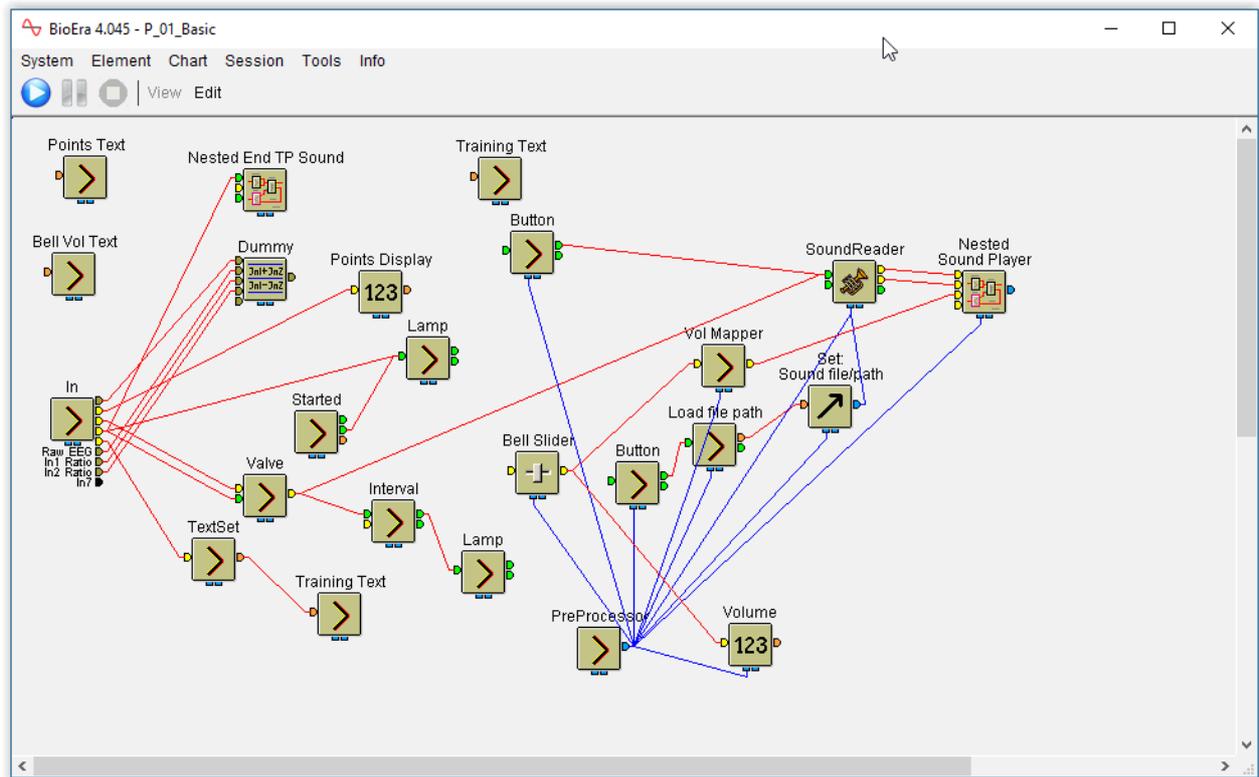
• Chart elements should be set to show in Runtime 2.

Figure 5.1 – BioEra designer