

Heart Coherence

Software Application User Guide

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1 Introduction

This guide introduces the Heart Coherence biofeedback application, part of the Mind-Body Training Tools suite. This set of applications is designed to develop skills in mind-body awareness and self-regulation, particularly in a context of mindfulness and meditation practice.

The application is designed to train Heart Coherence or Heart Rate Coherence (HRC). HRC is a mind-body state where heart rate variation becomes synchronised with breathing, a pattern known to correlate with emotional and physical well-being and optimal performance. (A fuller definition is presented later.) With biofeedback, we can train the ability to access HRC, and thus positive, adaptive and creative mental states.

The guide has two purposes: firstly to explain what HRV and HRC actually are and how they are measured, and secondly to teach you how to use the software – though it is more of a reference than a tutorial. Other training material is available on the StressResilientMind.co.uk website.

The application monitors both heart rate and breathing. Heart rate can be measured via either ECG or PPG. Breathing is measured via temperature of the inhaled and exhaled air.

In keeping with others in the suite, the HRC application was designed to support *your* aims, not to supplant them. Achieving good HRC scores is not necessarily the most important thing. Biofeedback should enhance or expand your subjective awareness rather than detract from it.

The guide assumes that you have read the Software Installation and Set-up Guide, and therefore know how to start the application.

The application works with several devices. For an up to date list of supported hardware, please see the StressResilientMind.co.uk website.

2 Launching the Application

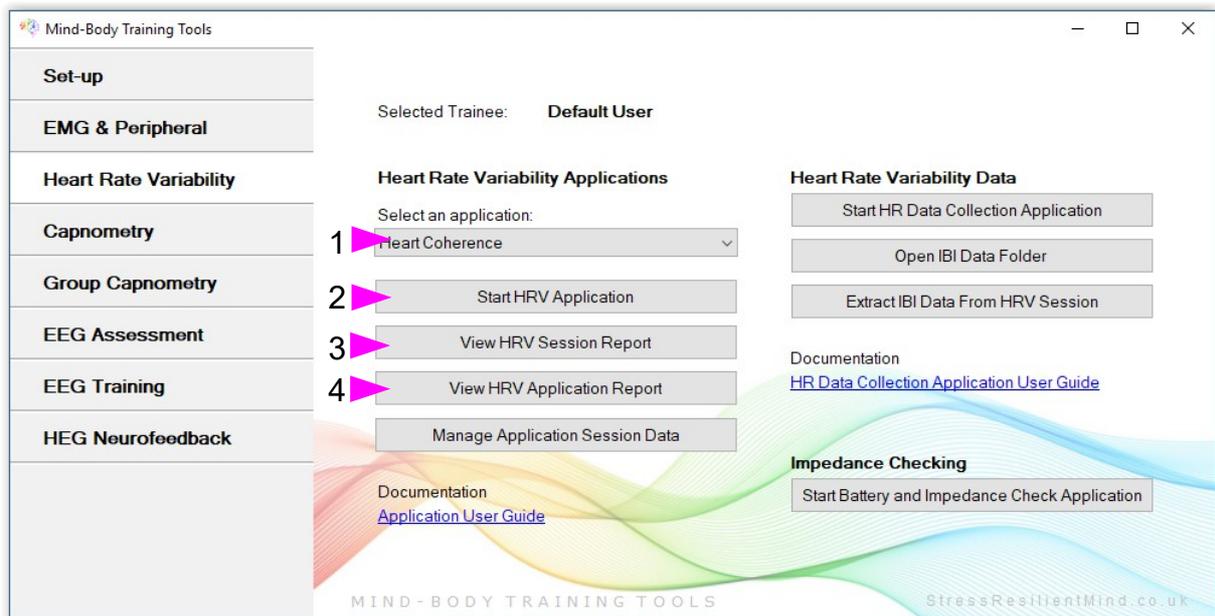


Figure 1 – Heart Rate Variability tab of the Platform application

Figure 1 above shows the Heart Rate Variability tab of the Platform application. First you need to select the “Heart Coherence” application from the drop-down list control (labelled 1). Then click the button to launch the app (labelled 2). Make sure you have your BioEra licence key (dongle) inserted into a USB socket. After a few seconds a new window will appear on your screen.

2.1 Hardware Set-up

The physical aspects of hardware set-up (how to connect and use your sensors, etc.) are dependent upon the type of amplifier you are using, and are covered in a separate document (Hardware Set-up Guide).

Before you start the application you configure the device set-up options, accessible by clicking a button in the Set-up tab of the Platform. In the dialog, select the type of amplifier (biofeedback device) you are using, in both the **HR** and **Breath** source controls. Note, all the source settings are remembered the next time you start the Platform. In the same dialog you should select the frequency of your local mains, e.g. 50Hz in the UK, though this only matters if your device uses ECG (as opposed to PPG). See the Installation and Set-up Guide for further details of device set-up.



Figure 2 – Amplifier status

You may select 'Simulator' in each of the source controls. In simulator mode, you can learn how to use the software without the encumbrance of actually sampling the breath. (The application simply uses recorded data as a source.)

Once you have started the application, you should see your device selection reflected in the device status display in the top right corner of the main window (see figure 2). The lamp (shown as a red square in figure 2) should change to green when you press the play button. If you do not see this happen, it means that the application has not been able to establish a connection with your device. Check it is plugged in and that the batteries are not flat.

For some devices, you'll see a button rather than just text. Pressing this button opens up a dialog that allows you to adjust settings related to the device, such as COM port. The specifics depend on the device – see the Hardware Set-up Guide for more details.

If you're using different devices for measuring HR and breath, you'll see two buttons (labelled 'H' and 'B' respectively, and also two lamps. Clicking the buttons allows you to configure device settings. For some device types there are no settings to configure so the buttons are inactive. Again the lamps should turn green when the devices start (the left for the HR device and the right for the breath device).

3 Physiological Parameters

This section explains the several physiological parameters used in the application.

3.1 Input Parameters

Heart Rate (HR) data is derived from either ECG (electro-cardiograph) or photoplethysmograph (PPG) signal, depending on your biofeedback device (device set-up is made from the set-up screen of the Platform and is covered in the Installation and Set-up Guide).

Breathing data is derived from temperature – specifically the temperature of inhaled and exhaled air, as measured at the nostril.

3.1.1 Heart Rate

The software detects each heart beat based on either ECG or PPG data. It calculates the Inter-Beat Interval (IBI) as simply the time between subsequent heart beats, and then this is converted into a heart rate in beats per minute (bpm). A heart rate is calculated for each beat (or IBI).

ECG gives a more accurate measure of IBI than PPG.

Movements can create artefact in the signal causing the software to miss beats. In the case of ECG, muscle tension in the arms or hands can also cause interference. Whilst there is a degree of tolerance, sometimes the software takes several seconds to recover. If the heart beat appears to be lost, simply sit still and wait. In the worst case you may need to stop and restart the application.

You can observe the “raw” signal (ECG or PPG), and beat detection, in the support window (see figure 17 in section 4.2).

3.1.2 Breath

From the changing temperature of inhaled and exhaled air, the system is able to detect the turning points of the breath and therefore derive breathing rate. This method depends on a reasonable current of air coming through the nostril, so if your nose becomes blocked it will stop working. Speech will also disrupt the normal air current, and will give rise to unreliable breathing calculations.

Breathing Calibration

The breath detection method requires a short period of time to calibrate to your breath. This happens automatically during the first 20 seconds of any session (i.e. after you press 'play'). It's important that you breathe naturally and evenly, and not too slowly, through the nose, during this time. Note that the breath signal will not display properly until proper calibration is established.

Manual Re-calibration

If for any reason you lose reliable breath detection during a session (e.g. you have to remove and reattach the sensor) there is a way to recover: in the support window, there is a button labelled

'Calibrate', that you simply press. You should breathe naturally and evenly and not too slowly for a few breaths prior to pressing.

Generally the breath detection once established is very reliable and you should not need to re-calibrate during normal use.

Figure 3 shows you what a well-calibrated breath signal looks like (in the support window). The upper trace is the temperature of inhaled / exhaled air, while the middle trace is its first derivative or gradient. The yellow dotted lines are thresholds used for the detection of the breath turning points. They should be reasonably far apart, but close enough to the centre that the trace will easily and consistently cross to register a turning point.

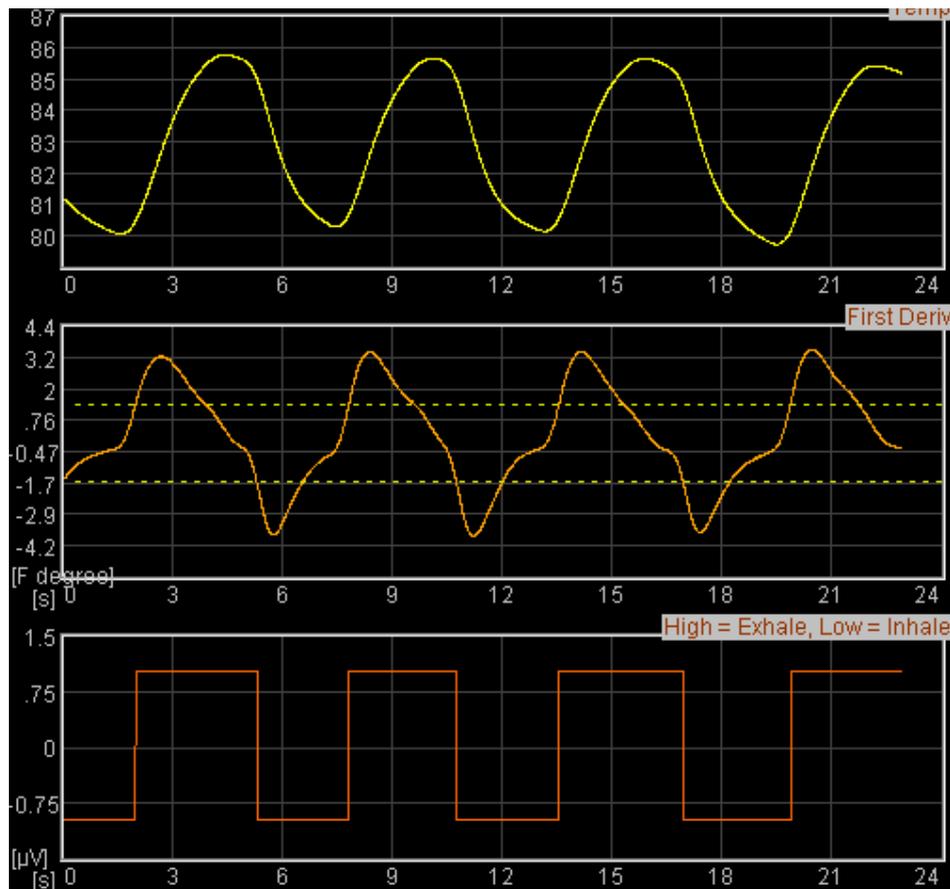


Figure 3 – A well-calibrated breathing signal

3.2 Derived Breathing Parameters

From the detection of the breath turning points, the software calculates:

- breathing rate, and average breathing rate (the averaging period is 1 minute)
- the ratio between the (durations of the) inhalation phase and exhalation phase of the breath. This is shortened to 'I:E Ratio' (or simply 'I:E'). A 1-minute average is also calculated.

These two are shown in numeric displays and in the long term display (see section 4.1.4) and can be used as the basis of audio feedback.

3.3 Heart Coherence Parameters

In the software two parameters relating to coherence are calculated; these are known as 'Coherence Score' and 'Synchrony'. The application also performs spectral analysis of the HR data, an alternative means of quantifying coherence. These concepts are described in detail in this section.

3.3.1 What Is Heart Coherence?

A healthy heart has a natural beat-to-beat variation in rate, known as Heart Rate Variability (HRV). Coherence is a natural and reflex-like rhythm in the HRV, which research has shown to correlate to both physical and emotional well-being – that's why it's a useful biofeedback parameter.

In HRC (Heart Rate Coherence), changes in heart rate become synchronised to the breathing, such that it speeds up when you breathe in and slows down when you breathe out. Figure 4 below shows the pattern. The red trace is the heart rate while the green is breath. The red HR trace is stepped as it changes discretely at each heart beat. Note that it is the *variation* in heart rate that synchronises with the breath, not the heart beat itself (HR is much faster than breathing rate).

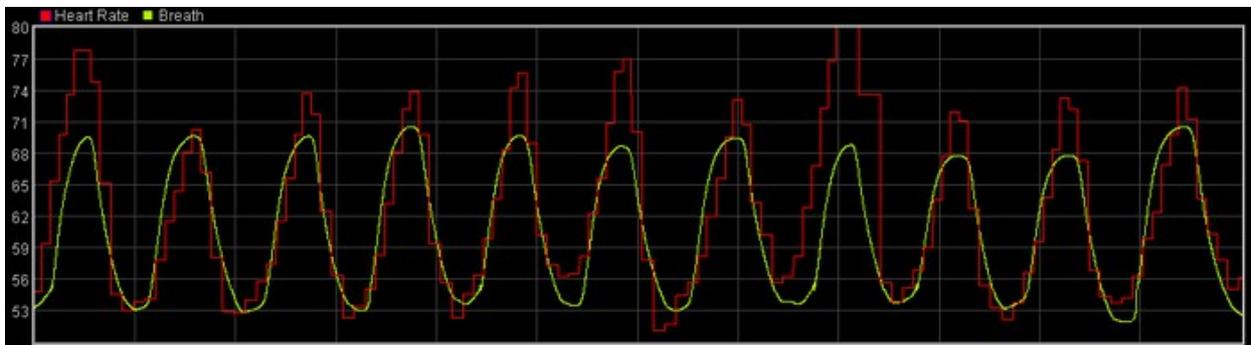


Figure 4 – showing relatively coherent heart rate variation. The red trace is heart rate and the green is breath. You can see the two are synchronised.

HRC normally develops when you are in an open, harmonious and emotionally positive state of mind – however negative emotions like anxiety and anger tend to disrupt it.

HRC can be quantified in various ways. High coherence involves regular large swings in heart rate. Clearly the degree of coherence depends on how you breathe – a slow regular breath at around 6 breaths per minute maximises the coherence (6 bpm seems to be a kind of resonant frequency).

3.3.2 Physiology of Heart Rate Variability

The physiological mechanisms behind HRV are complex, and largely beyond the scope of this guide. Understanding them isn't necessary in using the application. This section summarises what is known about the physiological mechanisms, but may be skipped if you prefer.

The pattern of HRV is strongly influenced by Autonomic Nervous System (ANS) functioning. The ANS governs many of our automatic and visceral responses. It has two branches, the sympathetic (associated with the “fight or flight” or stress response) and the parasympathetic (associated with “rest and digest”). So the two functions are largely opposite and mutually inhibiting, like a car's accelerator and brake, or like the two arms of a see-saw.

Both branches influence HR - the sympathetic NS raises it while the parasympathetic lowers it. When the parasympathetic is active, its influence is applied to the heart during exhalation, while during inhalation this influence is blocked. It is this mechanism which largely drives the rhythm in

the heart rate (or heart wave), and also explains why the heart wave is synchronised with the breath. (The phenomenon is also known as Respiratory Sinus Arrhythmia or RSA.) When the breathing is slow, the rhythm is augmented by another physiological mechanism called the baroreceptor reflex. This is why HRC displays a kind of resonant frequency at around 6 bpm.

Conversely, sympathetic arousal tends to flatten out the heart wave, or at least break the coherence rhythm in favour of a more chaotic variation. It's quite easy to experience this effect in HRC training, where even distracting thoughts and images can provide the necessary stimulus.

3.3.3 How Is HRC Measured?

This section explains how HRC is quantified. For this software I developed innovative methods, not available in other biofeedback products.

Considering HRC more closely, we can say that three factors characterise good coherence.

- i) The swings in HR over the cycle of the breath are large – the heart may speed up by 20 beats per minute or more during the inhalation, and then slow down again by the same amount during the exhalation.
- ii) The changes in HR are consistent or stable over the course of successive breaths.
- iii) The HR rhythm (or 'heart wave') is tightly coupled to the breath – in other words, the maximum heart rate occurs at the same time as the end of the inhalation and beginning of the exhalation, while the minimum heart rate occurs at the opposite turning point.

The application's two main HRC parameters (coherence score and synchrony) attempt to capture these characteristics – the former two especially in the coherence score, and the latter in synchrony.

Most biofeedback applications quantify HRC using spectral analysis, or Fourier analysis. This application also offers spectral analysis, though it is not used to calculate coherence score or synchrony.

Coherence Score

This section describes in some technical detail how the coherence score is calculated. It certainly isn't necessary to understand these details in order to use the application, so you may skip over the section entitled 'algorithm'. However it is worth summarising some features:

- Coherence is calculated over a moving window of 5 breaths, meaning it can be relatively slow to change, and not necessarily easy to achieve a score above zero.
- When the synchronisation between breath and heart wave is lost, the coherence score quickly goes to zero. I believe this offers an advantage over the usual spectral analysis-based methods.

Coherence Score Algorithm

For those interested, the method is as follows:

- At the beginning of each inhalation, the minimum HR for the preceding exhalation is noted.
- At the beginning of each exhalation, the maximum HR for the preceding inhalation is noted.
- For each half-breath (either inhalation or exhalation), the difference between the above two is calculated – this may be thought of as the “amplitude” of the heart wave (figure 5 shows two successive such amplitudes).
- Using a moving window of 5 breaths (or ten heart wave amplitude calculations) we calculate the mean (average) and standard deviation (SD) of this heart wave amplitude.
- In good coherence, the mean will be large (reflecting the first of the above characteristics) while the standard deviation will be small (reflecting the second characteristic). So the coherence score is defined simply as:

$$\text{coherence score} = (\text{mean} - W \times \text{standard deviation}) \times S$$

In this equation W is simply a fixed weighting factor and S is a fixed scaling factor, chosen so that a score of 100 represents very good coherence (though it is not a maximum).

In the user interface coherence score is usually shortened to HRC.

Synchrony

In the context of this application synchrony is defined as the difference in seconds between the time of the maximum heart rate, and the time of the minimum breath temperature, which occurs at the top of a breath (between the end of inhalation and the beginning of the exhalation) – see figure 6.

- Synchrony is calculated once per breath. It can be positive or negative.
- A positive synchrony means that the breath turns around before the heart wave – the heart wave is following the lead of the breath.
- A negative synchrony means that the heart wave turns around before the breath – the breath is following the lead of the heart wave.
- If there is no degree of HRC, synchrony will still be calculated but it will be meaningless.

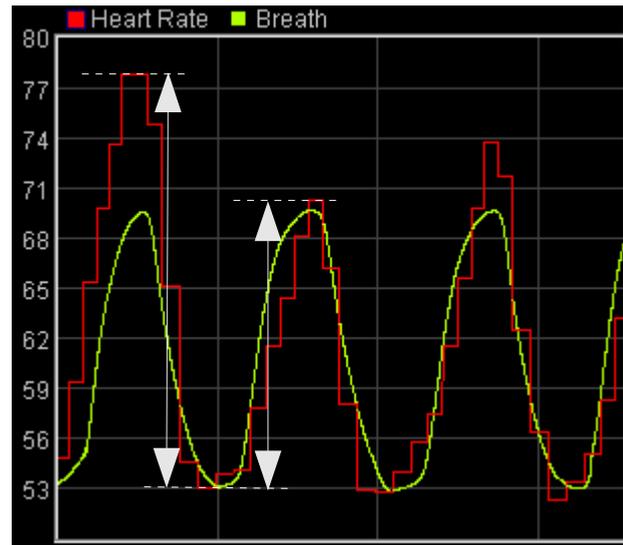


Figure 5 – two successive HRV “amplitudes” are highlighted. These are used to calculate coherence score.

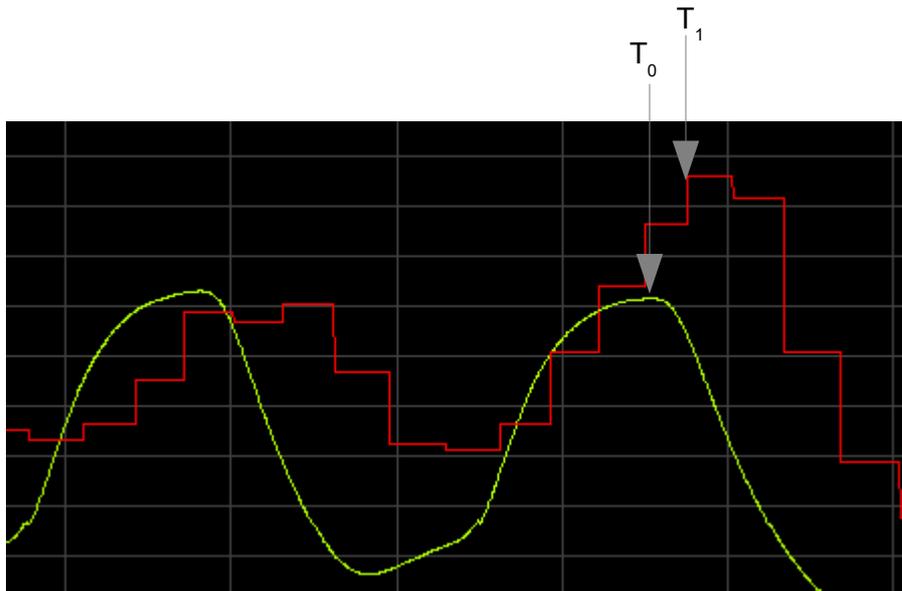


Figure 6 – Definition of Synchrony:
Time of Max HR (T_1) – Time of Breath Turning Point (T_0)

In some parts of the software, described later, average values of synchrony are used. Two variants in particular are calculated:

- The average of the magnitude of the synchrony – the sign (positive or negative) is dropped. This is because the actual average is likely to be close to zero, which is in some sense misleading as it may not capture the difference between a tight synchrony varying either side of zero, and a loose synchrony of larger magnitude.
- The average of the actual synchrony – sign included. This measure has the advantage that it will express whether the breath is consistently ahead of (or following) the heart wave.

In both cases the averaging is over six breaths.

Spectral Analysis

As mentioned, spectral analysis is an alternative means of quantifying HRC. The application does not base its feedback on this method, but a spectral analysis display is included in the support window for those interested. This section explains the essential meaning of spectral analysis in a mathematically non-rigorous way. It is still rather technical but can easily be skipped over.

Spectral analysis is a mathematical transformation of the heart rate data. The starting point is a set of values of successive inter-beat intervals (IBIs). When arranged sequentially and graphed, we would see a pattern that would look a lot like the heart rate trace which the application presents. In cases where good coherence is present, we would see a regular wave (as in figure 4). Regular waves in their pure form are known mathematically as sine functions.

Fourier's theorem states that any complex oscillation can be reproduced by adding together lots of sine functions, with differing frequency (or wavelength) and magnitude (or height).

Figure 7 below expresses this idea pictorially – three different sine waves are shown (blue, green and red traces), plus a more complex oscillation in white, which is simply the result of adding the first three together.

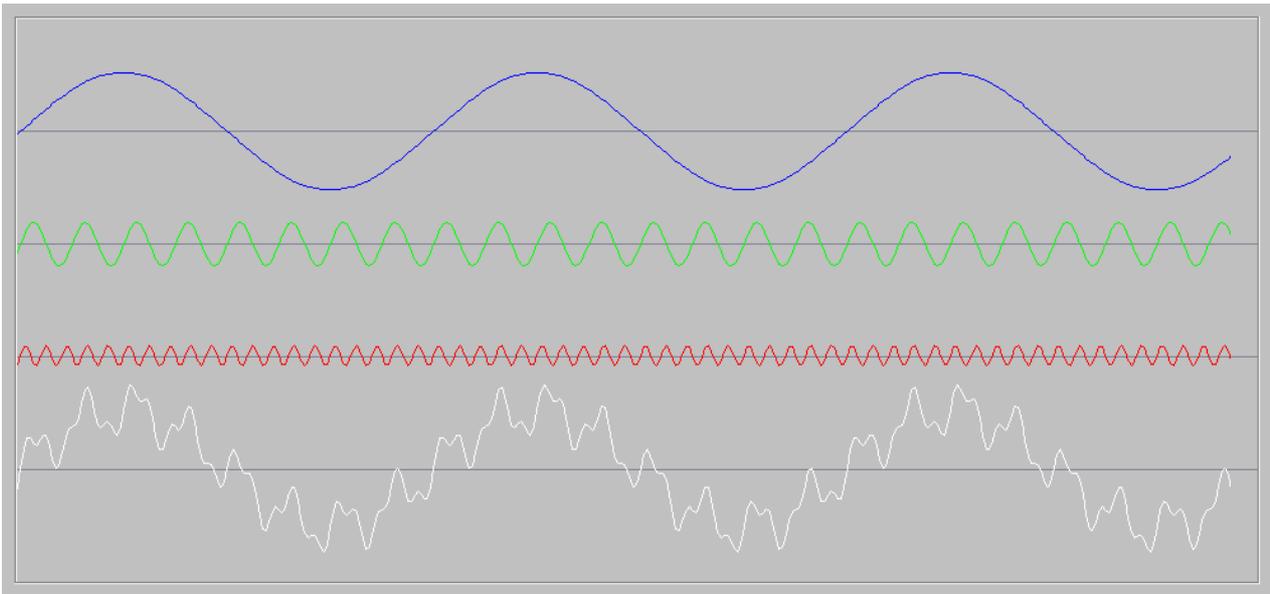


Figure 7 – the three upper traces (blue, green and red) are pure sine waves of differing frequency. The more complex white trace is simply the upper three added together.

Spectral analysis is the inverse process – breaking a complex oscillation down into component sine waves. This analysis can be expressed in a new graph – figure 8 shows an example. Each point on the horizontal axis now represents some particular frequency (or wavelength), and the height of the graph at that point represents the size, or the amplitude, of that particular component sine wave.

Figure 8 shows the spectral analysis of the composite white oscillation in figure 7. Hopefully you can see how it makes sense. Each of the three peaks corresponds to one of the component sine waves. Each peak's height correlates to the amplitude (height) of its associated sine wave.

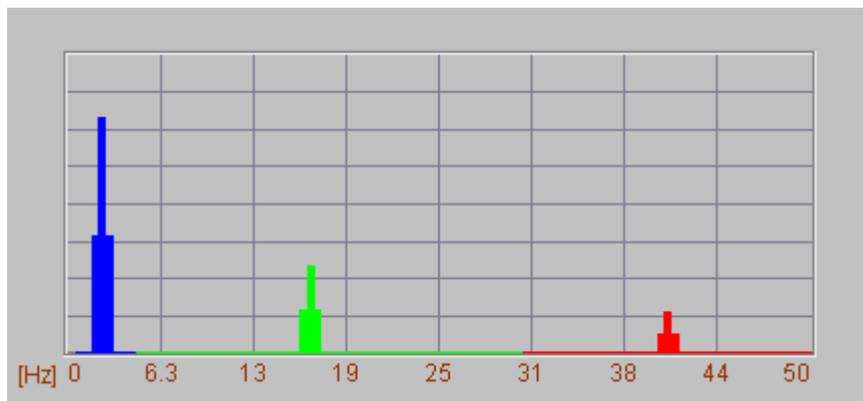


Figure 8 – spectral analysis of the white composite oscillation in figure 6 above. The three peaks correspond to the three component frequencies.

Returning to heart rate data – I hope you can now see that the spectral analysis of coherent heart rate data, since it looks a lot like a sine wave to begin with (see figure 4 for an example), will have one dominant and sharply defined peak. Figure 9 shows an example. The frequency of this peak is approximately 0.1 Hz (1 Hertz means one cycle per second). Since we know that the breathing follows the heart wave, we can infer that this data resulted from breathing at 6 breaths per minute (=0.1 breaths per second).

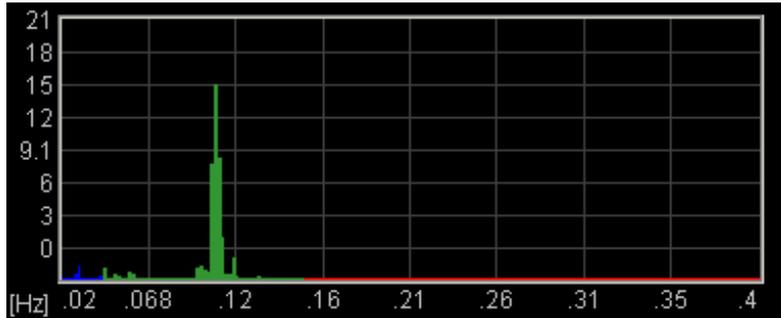


Figure 9 – Spectral analysis of HR data with a fairly high degree of coherence, reflected in a single sharply-defined peak

In performing spectral analysis one must always make a decision on “sample size” - how many IBIs (in our case) to include. Biofeedback applications use a moving window, or the most recent n IBIs. The spectral analysis is not therefore fixed but changes over time.

Figure 10 shows the spectral analysis that resulted from a period of breathing at 8 breaths per minute, followed by a short period of breathing at 6 breaths a minute. The heart wave was coherently synchronised with the breath throughout. Because the window (sample size) was large enough to include both periods, we see two peaks, one for each breathing rate. So you can see how a spectral analysis does not represent a single snapshot of time, but rather an average, in some sense, over a defined period of time.

Figure 11 below shows the spectral analysis of a much less coherent set of heart rate data.

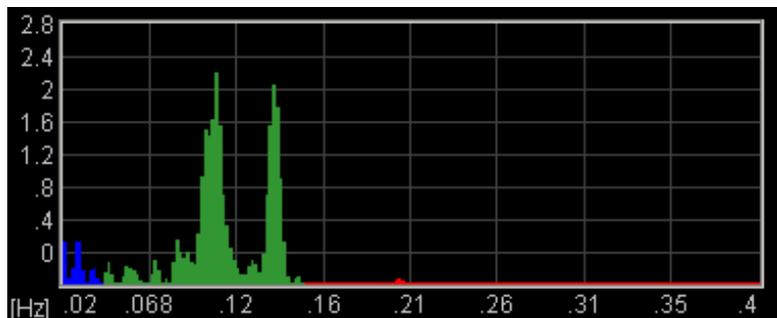


Figure 10 – Spectral analysis corresponding to a period of breathing first at 8 bpm followed by 6 bpm

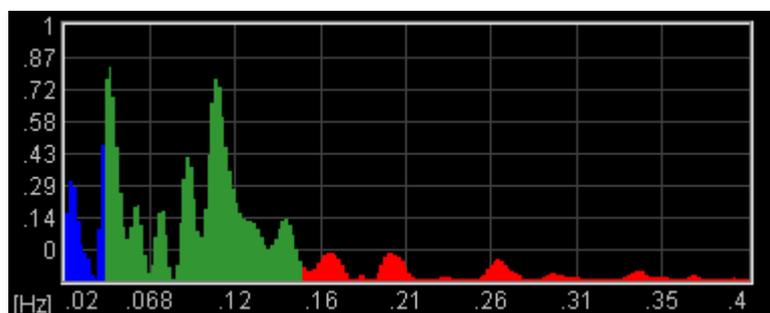


Figure 11 – Spectral analysis of relatively incoherent HR data

The frequency range of HRV spectral analysis is traditionally divided into three. The standard bandwidths are given in the table below.

VLF (Very Low Frequency)	0.0033 – 0.04 Hz
LF (Low Frequency)	0.04 – 0.15 Hz
HF (High Frequency)	0.15 – 0.4 Hz

As mentioned earlier, HRV is strongly influenced by ANS functioning, and indeed HRV is commonly used to assess ANS balance. “Activity” in the HF region is often interpreted as a reflection of parasympathetic activation. Some sources link the LF band to sympathetic activation, while others link VLF activity to the sympathetic.

However, it is important to note that this kind of analysis applies to data collected under “everyday” conditions – not during HRC training. For an adult the average breathing rate is 12-14 bpm, which is in the HF range. HRC with slow breathing, around 6 bpm, will pull the “breathing peak” down into the LF range, so in this case the LF range will predominantly reflect parasympathetic activation. The physiology is complex and one should be wary of over-simplistic interpretations.

4 User Interface

When you first start the application from the Platform, you will see two windows. The main window is shown in figure 12 below, while the support window is shown later (figure 17).

I expect that most users will have little use for the support window. You can use it to check that the application's algorithms are working properly, i.e. that heart beats and breath turning points are being accurately detected (see the discussion of breath calibration in section 3.1.2).

4.1 Main Window

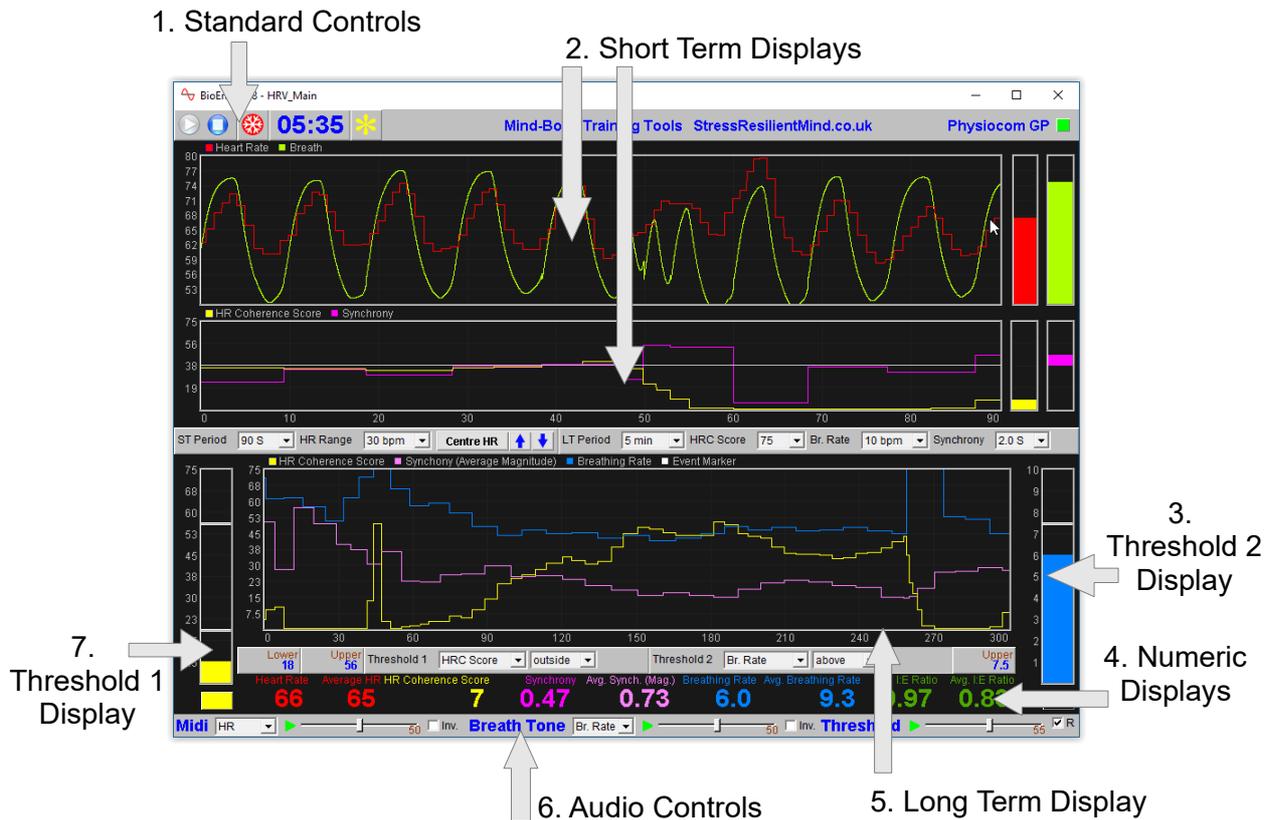


Figure 12 – Main window

4.1.1 Standard Controls (Start / Stop, etc.)

A set of buttons – Play, Stop and Pause – are the same in all the applications in the suite. They should be self-explanatory.

The button marked with a red asterisk is a simple event marker. You can use it to mark adventitious happenings and changes in session conditions (e.g. you turn on or off breath pacing). It is particularly useful for coaches and therapists. Events thus marked are represented in the long term chart (see section 4.4 below) by a vertical white line. They are also recorded in the session data file and are shown in session report charts (as dotted vertical lines) (see section 5).

Note that pressing the escape key during a session has the same effect as pressing the red asterisk with your mouse (i.e. it is an alternative).

4.1.2 Short Term Displays and Controls

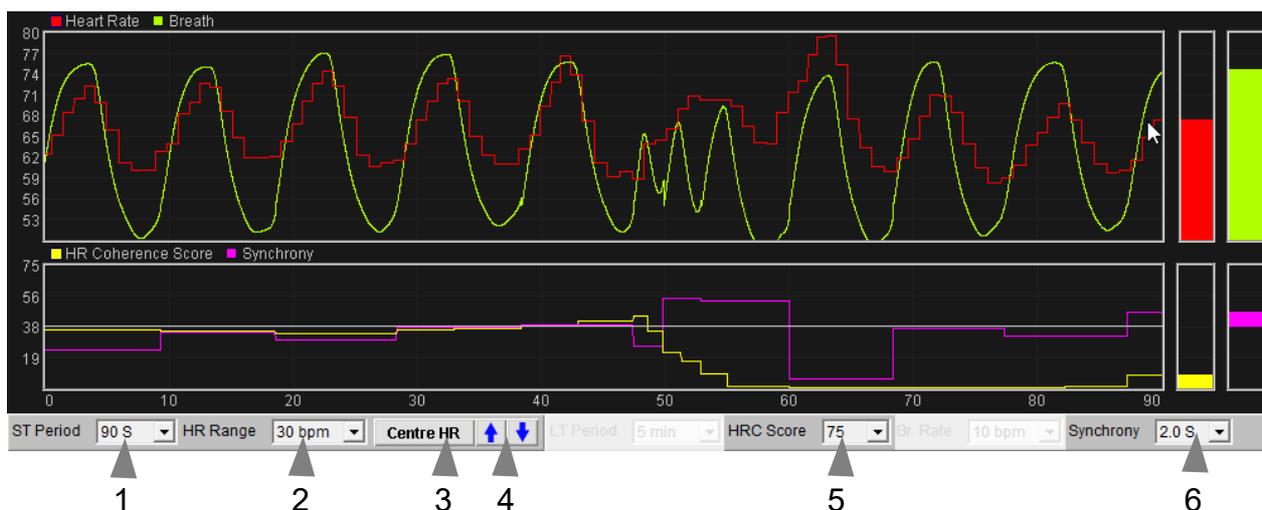


Figure 13 – Short term displays and controls

The two charts of the short term display show HR (red), breath (green-yellow), coherence score (yellow), and synchrony (magenta).

The following controls, positioned below the charts (1 to 5 in figure 13), control the ranges or scales (horizontal and vertical).

ST Period This controls the length of time it takes for the trace to traverse the whole chart from right to left – or in other words the horizontal range. It applies to both charts, so that the two will always be synchronised.

HR Range Controls the difference between the upper and lower limits of the Heart Rate display (red trace, upper chart).
Change this if the HR trace looks too bunched up or stretched out vertically.

Centre HR Trace (Button) Pressing this button centres the red heart rate trace to the middle of the chart – i.e. it causes the trace to be shifted either up or down (preserving the range). You can use this if the trace is disappearing off the top or bottom of the chart. The trace is automatically centred after the first minute of the session.

HR Trace Up, Down (Buttons) These two buttons give fine control over the vertical position of the HR trace, while keeping the scale constant.

HRC Score Controls the vertical range of the coherence score (yellow trace, lower chart). Note the same control sets the range in the long-term chart too (see section 4.1.4).
The lower limit is always zero.

Acts like a sensitivity control, or a “challenge level” control. Set it low if you are new to coherence training and higher as you gain competence.

Click the yellow square (upper left of chart) to see the coherence score range displayed in the chart.

Synchrony Controls the range of the synchrony score (magenta trace, lower chart). Note the same control sets the range in the long-term chart too (see section 4.1.4).

Remember that synchrony can be positive or negative. The middle of the chart is the zero line, the upper limit is +Range and the lower is -Range. Aim to have the trace lie as near to zero (centre) as you can.

Again, it acts like a sensitivity control – set it to be smaller the more adept you become with training.

Click the magenta square (upper left of chart) to see the Synchrony range displayed on the chart.

Note there is no vertical range control for the breath signal. This should automatically be adjusted to fit the display, during the calibration process. (If it goes off the top or bottom, it means recalibration is needed. Use the recalibrate button in the support window, as described section 3.1.2.) Each breath starts from the same point on the vertical axis – sometimes you see this as jumps in the signal.

4.1.3 Numeric Displays

These are positioned at the bottom of the main window, just above the audio controls, and should be self-explanatory.

Averages are calculated over a 60 second interval.

4.1.4 Long Term Display and Controls



Figure 14 – Long term display and controls

The long-term chart displays coherence score, synchrony and breathing rate, much like the short term displays but over a longer time scale. The controls (drop-down lists) are positioned above the chart (1 to 4 in figure 14) and are similar to the short-term controls.

LT Period Sets the horizontal range or time scale.

HRC Score Controls the vertical range of the coherence score (yellow trace). Note the same control sets the range in the short-term chart too (see section 4.1.2). Click the yellow square (top left of chart) to see this scale displayed.

Br. Rate Controls the vertical range of the blue breathing rate trace. Click the blue square

(top left of chart) to see this scale displayed.

Synchrony Controls the range of the synchrony score (magenta trace). Note the same control sets the range in the short-term chart too (see section 4.1.2).

The long-term chart displays the average magnitude of synchrony (i.e. the + or – sign is dropped).

Click the magenta square (upper left of chart) to see the synchrony range displayed on the chart.

4.1.5 Threshold Display and Controls

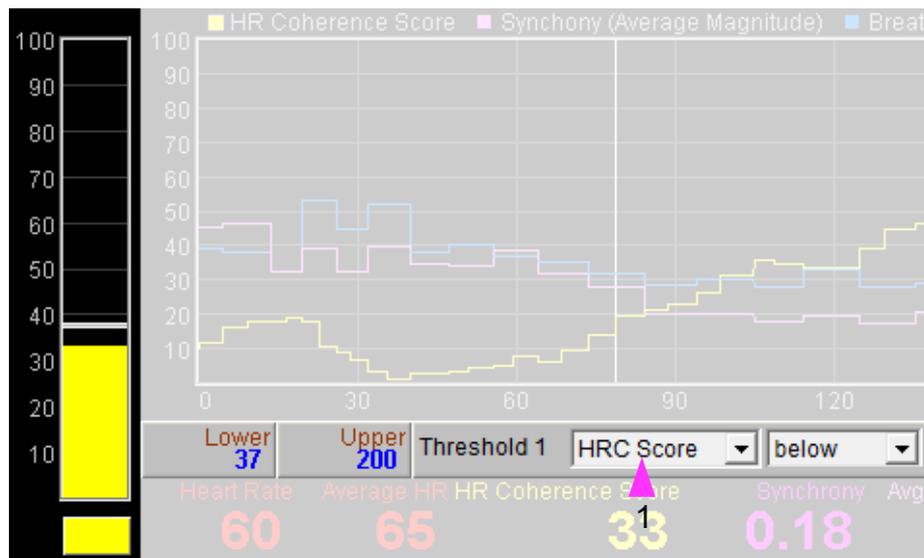


Figure 15 – Threshold 1 display & controls

Threshold-based feedback is designed to follow a consistent pattern throughout all the applications, and therefore it made sense to describe threshold functionality in a single place, viz. The Guide to Audio and Threshold-based Feedback (a separate document). I recommend you read that before trying to make sense of this section.

(Controls for threshold-based audio feedback are covered in section 4.1.6 below.)

In the HRV application there are two threshold displays, found at left and right sides of the application's main window, labelled 3 and 7 in figure 12 above. Threshold 1 on the left is shown in figure 15.

For each threshold you can choose the feedback parameter via a drop-down list control – in figure 15 this control is labelled 1.

For threshold 1 the options are: heart coherence score, synchrony (magnitude), average synchrony or breathing rate.

For threshold 2 the options are: heart coherence score or breathing rate.

As an example of how you might use threshold-based feedback, suppose you wish to maintain a steady breathing rate of around 6 breaths per minute with your coherence score maintained above 50. Use threshold 1 to set the coherence condition. Set its parameter to be HRC score (using control 1 in figure 15), then set its condition to be “below”, then drag the level to around 50. Use threshold

2 to set the breathing rate condition. Set its parameter to be breathing rate, set its condition to be “outside”, then drag the threshold levels so that the upper is say around 7 bpm and the lower is say around 5 bpm. You will probably want to turn on audio feedback for the threshold feedback, which is covered in the next section.

4.1.6 Audio Feedback Controls

Again, audio feedback functionality is consistent between applications and so is described in one place, i.e. The Guide to Audio and Threshold-based Feedback, which you should read before trying to make sense of this section.

Figure 16 below shows the controls available for audio feedback.



Figure 16 – Audio feedback controls

Midi

When activated, a musical note is played once per breath whose pitch reflects the chosen feedback parameter.

Drop-down list control (1) in figure 16 above sets the parameter for midi feedback. The options are: Heart rate; heart coherence score; synchrony; breathing rate; I:E ratio; threshold 1 (ratio); inverse threshold 1 (ratio); threshold 2 (ratio); inverse threshold 2 (ratio).

You can opt to invert the parameter-to-pitch mapping using the checkbox control (4 in figure 16) so that a higher reading (e.g. of heart rate) produces a lower-pitched note.

Breath Tone

To recap, a tone is played which follows the breath, and whose pitch reflects the selected feedback parameter.

Control 5 in figure 16 allows you to choose which parameter to use as the basis of feedback. The options are:

Heart coherence score; average synchrony; breathing rate; I:E ratio; threshold 1 (ratio); inverse threshold 1 (ratio); threshold 2 (ratio); inverse threshold 2 (ratio).

As with midi feedback, you can opt to invert the parameter-to-pitch mapping using the checkbox control (8 in figure 16) so that a higher reading (e.g. of coherence score) produces a lower-pitched sound.

Threshold

To recap, a sound is played whenever one of the threshold parameters goes out of range (or comes back within range). Function depends on the settings of the threshold controls covered in section 4.1.5 above.

4.2 Support Window

Figure 17 shows the support window. It displays the raw signals (either ECG or PPG for heart rate, and temperature for breath) together with various stages of processing in the heart beat and breath detection algorithms.

Temperature and breathing related data are shown in the left half of the window.

Breathing calibration was covered in section 3.1.2 above. The charts on the left show the various stages of the algorithm for detecting the turning points in the breath.

The horizontal yellow dotted lines are the thresholds for detection of the breath turning points.

The two lamp displays at the bottom (shown turned off) will flash briefly whenever the application detects (i) beginning of the exhalation (left), and (ii) beginning of the inhalation (right).

Press the button labelled 3 in figure 17 to recalibrate the breath as described in section 3.1.2.

The right half of the window shows charts related to heart rate data. At the top you see the raw heart signal (either ECG or PPG depending on what device you are using). The initial trigger for beat detection is when this signal crosses the dotted yellow line. You can adjust the relative position of the dotted line using the drop-down list control (1 in figure 17) – this may produce a more accurate heart beat detection.

The next chart down shows a digitised heart beat signal. Then below this a chart shows IBI variation, then the bottom chart shows the spectral analysis of the IBI data. Spectral analysis was described in section 3.3.3 above. The drop-down list control labelled 2 in figure 17 allows you to set how many data points the spectral analysis is based on – in other words what time window is used. To repeat, the spectral analysis has no bearing on the application's calculation of coherence score.

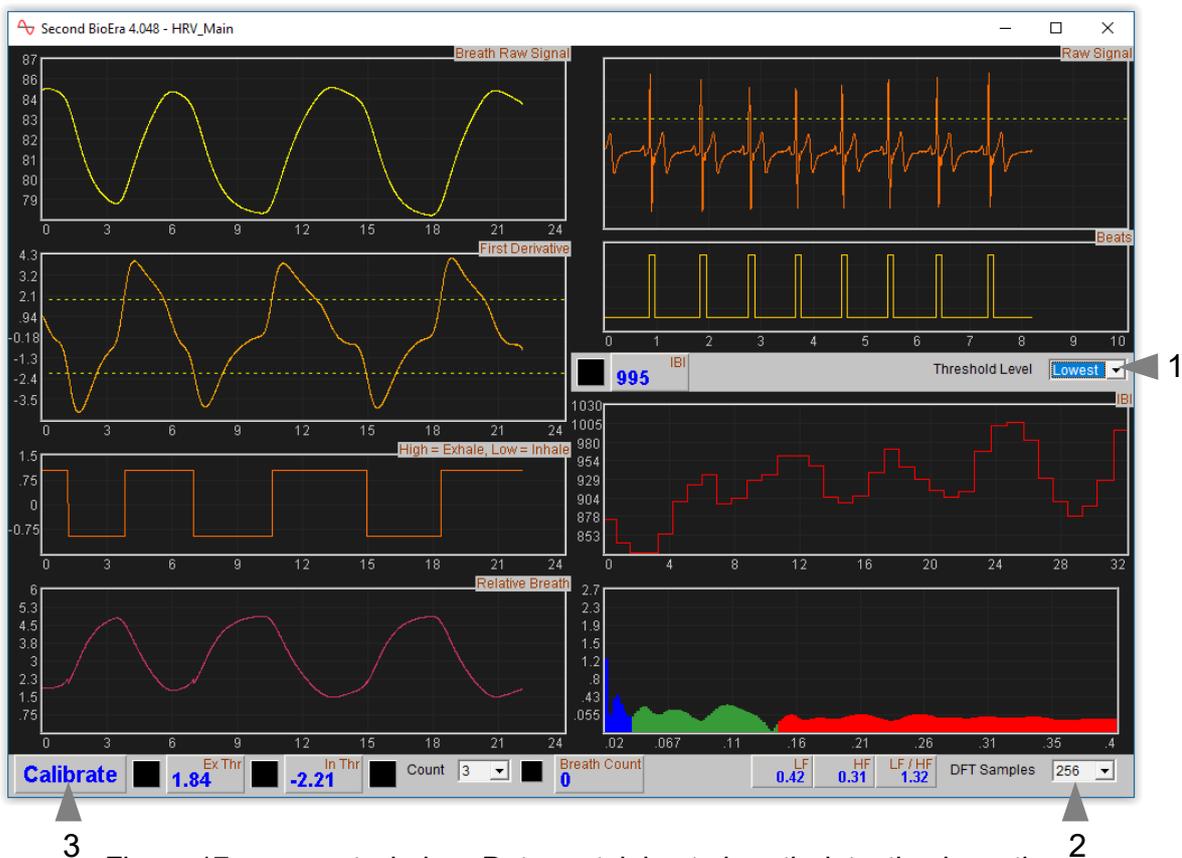


Figure 17 – support window. Data pertaining to breath detection is on the left, while heart rate data and controls are on the right.

5 Session Reports

The application records data so that you can generate a report for your sessions. The report contains summary data and graphs showing the progression of the feedback parameters over the whole session.

To generate and open a session report, click the button labelled 3 in figure 1. A dialog window opens in which you can select various options (see figure 18).

The software creates the report in html format. It will be opened using your computer's default web browser, e.g. Google Chrome. (Note that a live internet connection is not needed.) The html file is saved, so you can for example email it to someone. See the Installation and Set-up Guide for details of file storage.

Figure 18 – Report options

5.1 Report Options

Most of the options should be self-explanatory.

If you change your mind about options on seeing your report, you can regenerate the report by clicking the report button (3 in figure 1), then checking 'Overwrite existing report'.

Options relating to either heart rate data or breathing data are found under separate tabs.

Drop-down list controls allow you to set maximum or minimum values for several of the parameters. Setting these limits is a basic way of excluding “artefacts”, for example if you changed your posture during the session causing interference in the heart signal and leading to an inaccurate heart rate calculation. Data points outside the limits are excluded.

5.2 Adding Notes to a Report

You can choose to write some notes for your session report. Checking 'Add notes to report' (top right of the dialog) allows you to do this.

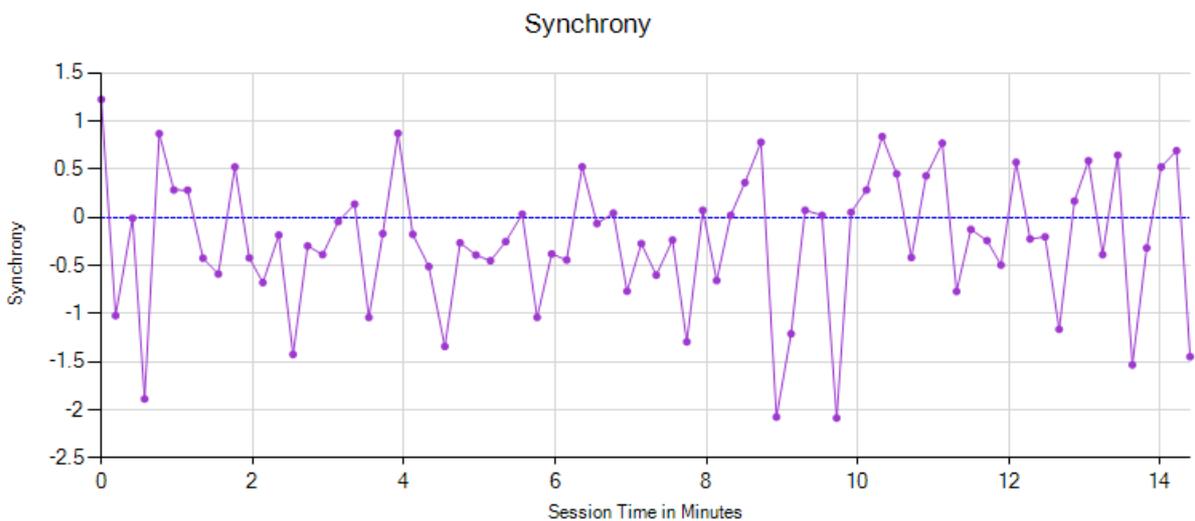
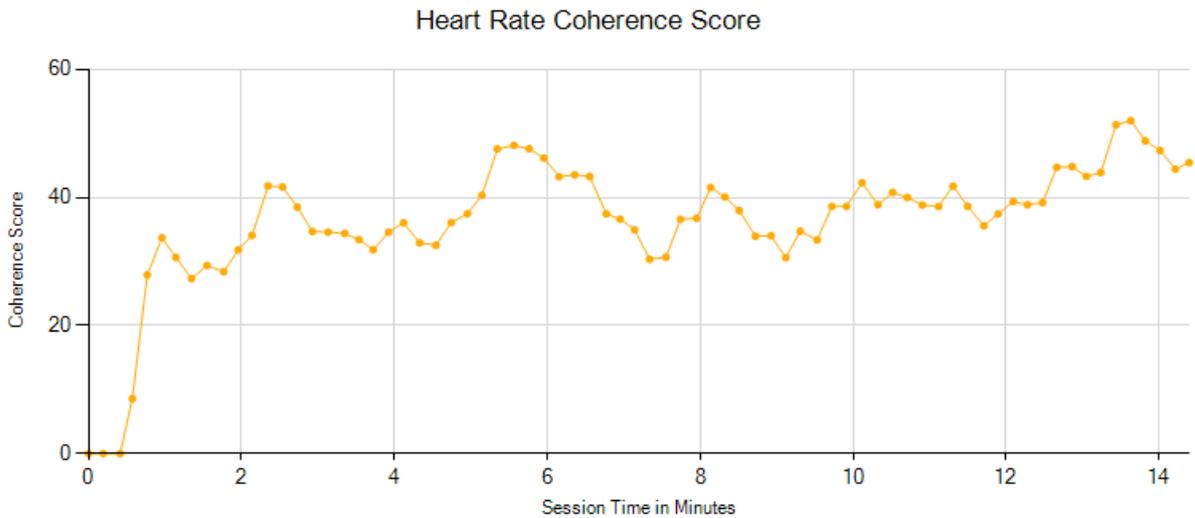
You may wish to add notes after having first seen the report. In this case, simply click the button (3 in figure 1) again, and check the 'Add notes' option. This will regenerate the report with your added notes.

5.3 Sample Session Report

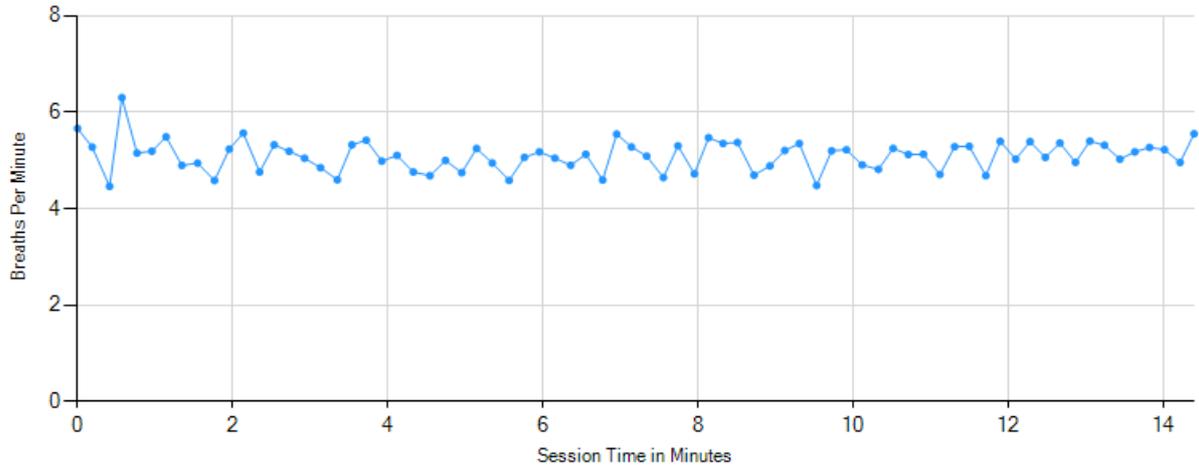
Please note, the formatting of the report has been changed slightly to fit this document.

Training Session Report

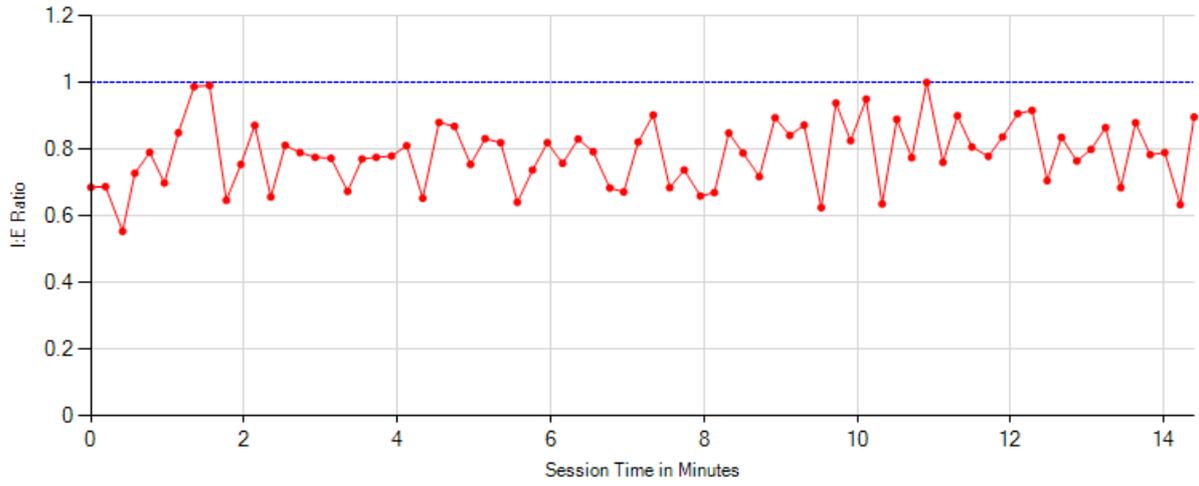
Training Application	Heart Rate Variability
User Name	Default User
Session Date	23/03/12 08:24



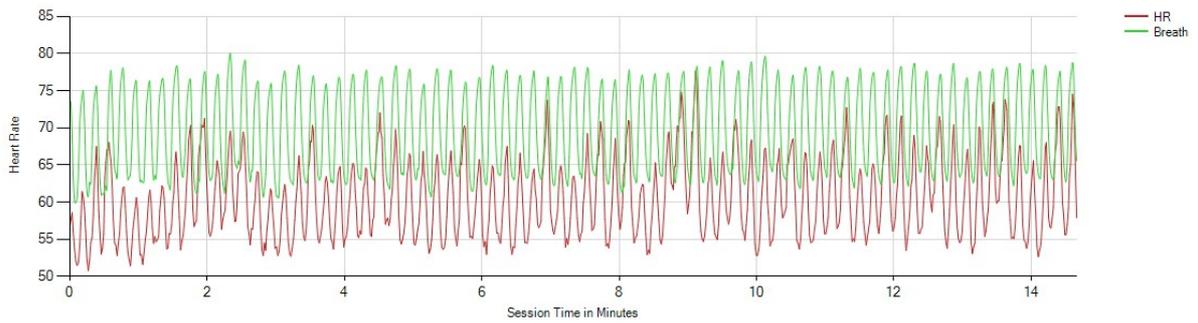
Breathing Rate



Inhalation to Exhalation Ratio



Heart Rate and Breath



HRC & Breathing Summary Data

Parameter	Mean	Max	Min	S.D.
HRC Score	36.4	52.0	0.0	9.9
Synchrony	-0.25 S	1.22 S	-2.09 S	0.71 S
Abs. Synchrony	0.58 S	-	-	-
Breathing Rate	5.1 bpm	6.3 bpm	4.5 bpm	0.3 bpm
I:E Ratio	0.79	1.00	0.56	0.10

Heart Rate Summary Data

Parameter	Value
Mean HR	60.5 bpm
Max HR	77.6 bpm
Min HR	50.8 bpm
SDNN	84.7 mS
RMSSD	42.3 mS

6 Application Report

An application report summarises all the sessions for the currently selected user, in charts and a table.

To generate and open an application report, click the button labelled 4 in figure 1. A dialog window opens in which you can select various options (see figure 19).

As with session reports, the software creates the application report in html format. It will be opened using your computer's default web browser, e.g. Google Chrome. (Note that a live internet connection is not needed.) The html file is saved, so you can for example email it to someone. See the Installation and Set-up Guide for details of file storage.

Figure 19 – Report options

6.1 Report Options

The application report options dialog is an adapted version of the session report options dialog. Many of the options are the same, and should be self-explanatory. See section 5.1 above.

As with all of the application reports in the suite, there is a chart for each of the main parameters tracked in the application – in the case of the HRV application that means coherence score, synchrony breathing rate and inhalation to exhalation ratio. For each chart you can opt for line graphs for the maximum, minimum and mean. (For synchrony the mean magnitude is shown too.) The line graphs have one point per session.

6.2 Sample Application Report

Please note, the formatting of the report has been changed slightly to fit this document.

Application Analysis Report

Training Application	Heart Rate Variability
User Name	Default User

HRV Session Averages

Parameter	Mean	Max	Min
Cohrence Score	52.41	74.21	0
Synchrony	-0.52	1.56	-1.87
Breathing Rate	5.85	8.63	4.9
I:E Ratio	0.78	1.12	0.54